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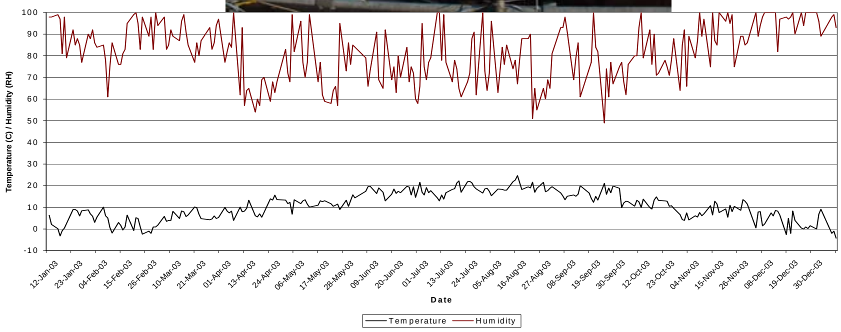
# The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2002-2003

Information Management Programme

Internal Report IR/04/032



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/032

# The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2002-2003

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*Key words*

Environment, Temperature, Humidity, Monologger, Thermohygrograph, Microtherm, Stevenson Screen, Core Store, Materials, Specimens

*Front cover*

Graph detailing weather readings at Keyworth & photograph of Murchison House 'weather station'.

(Photograph by G J Tulloch)

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# Foreword

This report is the published product of a study by the British Geological Survey (BGS) into the environmental conditions of certain storerooms under the control of the Corporate Collections Management Project at both the Keyworth and Edinburgh sites.


# Acknowledgements

The authors would like to thank those whose assistance in the delivery of the data over the period of reporting has made their task easier.

In particular Paul would like to thank Jon Bouch for setting up macros in Microsoft Excel, thus enabling quicker calibration of all the Keyworth data. I would also like to thank Pauline Taylor and Susan Martin for downloading the environmental data when I have been unable to do so.

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Photograph credits:

| | |
|---|---|
| Plates 1- 4, 6 – 14 | Paul Shepherd |
| Plates 5, 18 & 19 | Graham Tulloch |
| Plates 15-17 & 20 | Luis Albornoz-Parra |

# Contents

**FIGURES**



**PLATES**

**TABLES**

# Summary

This report presents the environment data gathered during the calendar year 2003 in the storerooms for the British Geological Survey's Corporate Collections Archives.

Comparisons are made with data collected in pervious years to assess the benefits or otherwise of modifications to either working practices or the fabric of the building.

The rationale for recording the environment, the location of the instruments and the equipment used to monitor and record data are described in chapter 1.

The data are discussed in chapters 2 and 3 where they are also illustrated in graphical format. A full copy of the data is contained on the accompanying compact disk, together with an Adobe Acrobat format version of this report.

Monitoring the environment has allowed certain measures to be taken that will not only have a positive impact on the conditions of the storerooms, and therefore the specimens held therein, but in some cases, on the condition of the fabric of the buildings.

We will illustrate that there are a number of factors that affect the temperature and humidity of a storeroom. These factors range from duration and number of workers present in the room to changing air movement by altering doors openings. Other factors include heating cycles of the building and external influences such as variations in the weather, from temperature and precipitation to the direction of the wind.

In some cases a change in working practices has all that has been required to improve the environment, in others building work has been required. In all cases none would have been obvious without the benefit of factual data.

Alterations to working practices and improvements in the fabric of the stores over the period of reporting will be discussed. Possible future modifications are identified, however these are made in a controlled manner to allow changes in the environment to be assessed.

# 1 Introduction into Environmental Monitoring

Monitoring the environment in sample stores is vital to the long-term strategy of the Corporate Collections Management Project. Recording fluctuations in the temperature and humidity within the store areas will, hopefully, pre-empt any potential problems with sample deterioration.

Standards in the Museum Care of Geological Collections, 1993 details the parameters in which rock & fossil material should be stored. Conditions outside these parameters or large variations within them can cause the acceleration of sample degradation, pyrite decay and efflorescence for example.

Without continual monitoring the environment of sample stores and therefore the possible threat to the samples cannot be accurately known.

### 1.1 AIMS AND OBJECTIVES

Strategy for Keyworth and Murchison House

- To routinely monitor the temperature and relative humidity in all storage areas of the collections and, where possible, monitor the external climatic variations, to determine what affect this has on any climatic variations within the Collections.

- Interrogate data and report to the appropriate authorities any adverse readings, which may indicate a defect in the building, e.g. structural, heating or ventilation, to allow action to be taken to prevent any damage or further damage to the collections.

- Use our knowledge of the internal climates to store the collections in the most suitable locations, where possible.

- To randomly monitor temperature and humidity readings in individual storage containers within the collections to determine if a buffering effect, from variations in the main storage areas, takes place.

- Recommendations and improvements should be made as required, based on the data collected, in order to preserve the collections for future generations.

A summary detailing the Strategy for Environmental Control can be found in Appendix 1.

### 1.2 ENVIRONMENTAL CONDITIONS WITHIN MUSEUMS

Any geological collection or any other type of collection, however small it is, that has a significant importance to an institution or the public, should be carefully maintained and preserved.

One of the most important factors is to monitor and control the environmental conditions within the collections.

Numerous geological materials are sensitive to certain components of the environment, which include relative humidity (RH), temperature, atmospheric chemicals, light and vibration. Brunton *et al* (1985).

The main environmental conditions to affect any collection are temperature and relative humidity. Variations in temperature are associated with its relative humidity. As a volume of air is cooled, it becomes more saturated, and less saturated as it is heated. Therefore any major changes in temperature especially rapid fluctuations should be avoided. Temperatures below 10°C should also be avoided because of high humidity values and the risk of condensation. The ambient storage temperature for geological specimens should be between 16-22°C. Doughty *et al* (1993).

Any geological collection can be potentially damaged or destroyed by relative humidity and are therefore sensitive to changes in humidity in the environment in which it they are stored. High humidity levels can lead to deliquescence, chemical change such as pyrite decay, and deformation of some materials through the absorption of moisture. Extremely low humidity levels can cause efflorescence and shrinkage of some moisture absorbent specimens, including shale and sub-fossil bone. For general geological materials the ambient relative humidity should be around 45-55%. *Child* (1994).

In addition to maintaining acceptable conditions for the general collections, some geological specimens require storage under different conditions; these are specified in Table 1. Where storage conditions are required outside of these limits, conditioned microclimates must be used.

| Material Type | Ambient Temperature | Ambient Relative Humidity |
|---|---|---|
| **General Collections** | 16-22°C | 45-55% |
| ***Sensitive Materials*** | | |
| Pyrites & Marcasite (and fossils containing these minerals) | 16-22°C | <55% |
| Sub-fossil bone, tusks, teeth: fossils with shale or clay matrix | 16-22°C | Not below 40%, |
| ***Historical Records*** | | |
| Documents on Paper | 13-18°C | 55-65% |

**Table 1: Ambient Storage Conditions for Geological Specimens (Doughty & Brunton, 1993)**

## 1.3 AREAS OF INVESTIGATION

The monitoring for this report has been undertaken at two sites within the British Geological Survey (BGS). These are located at Keyworth, Nottingham, and Murchison House in Edinburgh.

### 1.3.1 Keyworth

The monitoring of the collections in Keyworth began at the end of May 2001, with the use of the Casella Microtherm ICS 500+, which to this day, is situated on the first floor of the museum.

Additional monitors were obtained at the end of June 2001; these were two Casella Thermohygrographs, one being positioned in the main area of the core store and the other on the ground floor of the museum. This gave us a better foundation to start monitoring the environmental conditions within these storage areas. As soon as the funds became available three additional monitors were purchased in October 2001. These were in the form of Digitron MonoLogs and were positioned in additional areas within the core store. In February 2003 another monolog was purchased. It was decided that this logger would become a 'mobile logger', which could be located in areas that were causing a concern or to be used for additional comparisons within a storage area, such as the storage trays for specimens.

The Keyworth site houses numerous types of collections that come under the category of Corporate Collections. This includes the Borehole Collection, which contains over 3000 pallets of core from England & Wales, from 3000 boreholes. Together with over 600,000 registered samples from onshore UK boreholes and 1,500,000 cutting samples from 1,500 onshore UK oil wells.

The Palaeontological collection includes about a quarter of a million macro-palaeontological specimens of museum quality. Together with an additional two million specimens collected during mapping projects, which are still are of significant importance. This makes this the most important single collection of British fossils in the world.

The Petrological collection contains more than 200,000 specimens, which is used for reference purposes. This collection is made up of a suite of smaller collections, which includes England & Wales sliced rocks, reference minerals, museum reserve collection, building stones and private collections. *Hollyer et al* (2000).

The NGRC (National Geological Records Centre) is a unique archive of national importance containing over three million items with information dating back over 200 years. Since its inception, the National Geological Records Centre has maintained, collated, and indexed large collections of geological data. The Data Centre is a recognised Place of Deposit for Public Records and is also the Natural Environment Research Council's Designated Data Centre for data generated by research in earth sciences. *Bowie* (2000).

### 1.3.2 Murchison House Environments

The Collections of the Survey in Edinburgh are stored on two sites, Murchison House and Loanhead. These two locations contain the Palaeontological and Petrological collections and the Marine archive respectively. For the purposes of this report, only the Murchison House collections will be discussed.

The Palaeontological collection comprises approximately half a million specimens in 3 main sub-collections from Scotland and northern England: the working, or Survey Collection, the Museum, or Type and Stratigraphical Collection and the Palaeontological Slide Collection.

The Collections are housed in linked but separate stores in a variety of trays ranging from museum standard cabinets to lidded and open wooden and plastic trays.

The Petrological collection contains more than 130,000 specimens. As with the Palaeontological collection this collection comprises a number of sub-collections, including the Scottish sliced rocks, S&N, the Murchison, the Edinburgh and the Systematic collections. All of these collections with the exception of the Edinburgh & Systematic collections have associated thin sections. There are also a small number of reference minerals, and a growing number of building stones samples. *Hollyer et al. (2000)*. This collection is stored in two rooms, one containing cabinets for the thin section collection and one housing the remaining sub-collections.

These important Collections, both Palaeontological & Petrological, assist Survey field geologists in mapping projects and an increasing number of commercial activities; additionally external academic and commercial enquirers utilise the Collections in their studies. It is, therefore, important that the storage environment is as stable as possible in order that the integrity of the Collections is preserved.

The monitoring of the environments of the Edinburgh Collections store rooms commenced in December 2000 with a two-week survey in the Palaeontology store using three borrowed Digitron monologgers, type MLTHB16. The interval selected at that time was one reading every hour.

Monitoring recommenced in early 2001 when the borrowed equipment again became available and has continued without break to the present. The two week survey did not show anything that gave cause for concern and therefore the interval between readings was kept at hourly for no other reason other than it appeared adequate as it allowed the loggers to be in place for up to 4 months without any action being taken by staff. However, following a download late in 2002 the intervals were reduced to every 3 minutes starting on the hour.

Two localities were initially selected in reaction to suspected ingress of damp, or moist air through a now disused vent, the third was chosen to evaluate the difference in materials of specimen trays.

After a period of two months no significant temperature or humidity differences could be identified in different areas of the store and so the logger positions were changed to provide wider monitoring of the general store and the valuable museum collection.

As funds became available additional loggers were purchased and the monitoring extended to the Petrology store. There is now an array of 6 loggers in place: 3 in each store.

Data from an external logger set-up by another project has recently been made available. The logger is situated on the lower south roof of Murchison House and can provide temperature and humidity measurements every second although data is extracted for the same times as the internal loggers.

This data provides us with an excellent record against which we can compare the internal loggers. It allows the internal data to be evaluated and the possible source of any variations to be identified.

## 1.4 ENVIRONMENTAL MONITORS

Between Murchison House and Keyworth three different types of monitors are used to measure the temperature and humidity of the collections; an further two monitors measure external climatic variations.

### 1.4.1 Types of Monitors

#### 1.4.1.1 Digitron Monologger2

The MonoLog is a remote device that can measure temperature and relative humidity using two sensors, see Plate 1. Each “logger” is powered by a battery, which is used to save collected data until the device is downloaded via the communications interface to a personal computer. The loggers can be set-up to record data at any time interval, currently both Keyworth and Murchison House loggers have been set to a three minute time interval starting on the hour. Previously

Keyworth monitors had been set to a two-minute time interval. The data is downloaded on a weekly basis. This device is used at Keyworth and Murchison House.

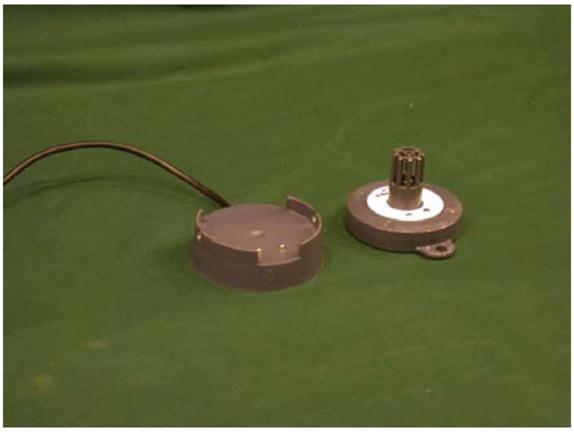

**Plate 1: Digitron MonoLog 2 with communications interface.**

The advantages of these monitors is that they are small and lightweight and can, therefore, been placed in almost any location. Parameters can be set manually and, if they are exceeded, are clearly shown on the data table. Once the data is saved to an .lcf (Logger Compact File) format, it can be read in tabular or graphical format using the software provided with the logger. These files can also be converted into a comma-separated value format (.csv) where the data can be imported into a spreadsheet or database software application, such as Microsoft Excel or Access. *Sifam Instruments Limited (2000).*

The disadvantages is that the logger cannot show an instant reading in any given location unless it is connected via the communications interface to a PC, however this can cause severe battery drainage.  The logger also needs to be downloaded on a regular basis or else the data stored can be lost.

#### 1.4.1.2 CASELLA THERMOHYGROGRAPH

The Casella Thermohygrograph measures temperature and relative humidity continuously via two pens connected to two sensors, which in turn draw coloured lines on a chart around a rotating drum. The unit is powered via a mechanical wind-up mechanism. The hygrograph is also portable and can be situated in any room where monitoring is required. This device is used on the Keyworth site. Readings are taken at every six-hour interval. See Plate 2.

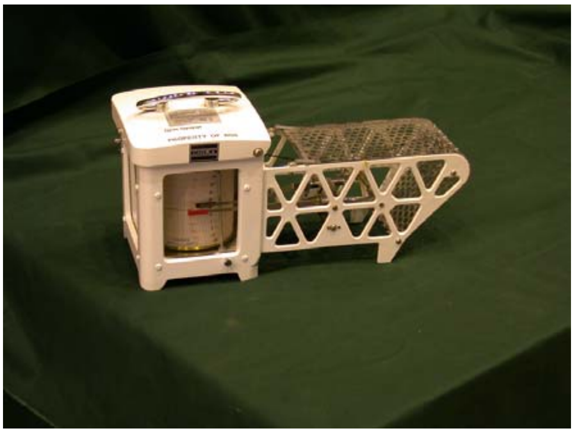

**Plate 2: Casella Thermohygrograph.**

The advantages is that the results produced on the graph are continuous, and can be viewed at any time when "passing by". Therefore it provides an indication of the environment at that time, and also when the graph is removed.

The disadvantages is that the hygrograph needs to be "wound-up" on a regular basis, normally twice a week, and the chart paper also needs to replaced on a weekly basis. Another problem is that the paper chart results need to be extracted manually and typed into Microsoft Excel if they are to be included with the digitally recorded data. The data can be visually extracted at two-hour intervals, but due to the time required to do so it is actually done at six hourly intervals. This still gives us a good indication of that environment.

#### 1.4.1.3 CASELLA 500 PLUS

The Casella Microtherm ICS 500+ can measure a variety of parameters depending on the number of sensors attached to the instrument. In our case four sensors are attached, a temperature and humidity probe, an air velocity probe, a natural wet bulb thermometer and a black globe thermometer. Unfortunately the temperature and humidity probe are producing inaccurate results therefore the black globe temperature sensor is used instead. This sensor integrates air temperature, solar radiation and air movement to give a temperature. Readings are taken every ten minutes, which are stored to the instrument and downloaded weekly. This device is used at Keyworth. See Plate 3


**Plate 3: Casella Microtherm ICS 500+.**

The advantages of this monitor is that the results can be viewed and analysed by using the instrument's software package, or converted into a format which can be read by Microsoft Excel or Access. The current results from the sensors can even be displayed on the instrument using scroll keys.

The disadvantages are that the device isn't as portable as the other loggers mentioned. The instrument needs a constant power supply, either mains or battery, but this monitor is powered by mains electricity and therefore isn't suitable for all locations. The results also need to be downloaded on a regular basis depending on the number of readings taken.

#### 1.4.1.4 STEVENSON SCREEN

The Stevenson Screen, or the weather station as it is known in Keyworth, consists of a wooden cupboard mounted on a steel frame, situated about a metre off the ground, Plate 4. The 'station' has a double roof, with louvered sides and some ventilation through the base. The whole screen is painted white and is situated in an open space away from any structures. A selection of readings can be taken from this station including dry bulb, wet bulb, maximum and minimum temperatures, grass minimum temperatures and rainfall. Visual observations for cloud cover, wind speed and direction are also taken. Readings are taken every 24 hours at 09:00 GMT (Greenwich Mean Time) over a five-day period, excluding weekends. Relative humidity readings are calculated by the difference between the wet bulb and dry bulb values, from this figure a value is then calculated using hygrometric tables. This monitor is situated at Keyworth.

**Plate 4: Stevenson Screen.**

The advantages of this station are that readings of external weather conditions can be taken throughout the year and a variety of thermometers and probes can be placed inside the station.

The disadvantages are that readings have to be taken manually at any given time, in all weather conditions. The thermometers only show current observed temperatures, whilst the maximum and minimum bulbs only show continual extremes in temperatures until the thermometers are reset daily. The wet bulb thermometer is feed via a muslin and wick placed in a distilled water reservoir, this has to be changed regularly and the reservoir has to be topped up.

#### 1.4.1.5 WEATHER STATION AT MURCHISON HOUSE

An automatic logger designed and built by BGS engineers using established monitoring instruments is used to acquire external temperature and humidity data.

The parameters are monitored and beamed to a computer every second although, for the purposes of this report, only 30-minute data is extracted from the database.

Although not situated in an ideal location it does provide us with continual readings to compare with those collected from the storeroom loggers.

The logger is situated on the south roof of level 4 of Murchison House. It is located on a pole 2.5 meters off the base of the roof, which is approximately 16m meters from the ground: see plate 5. It is 2.25 meters from the wall of an office and is therefore sheltered from the excesses of the weather that affects the north-facing storerooms.

**Plate 5: Weather station at Murchison House.**

There is no method of calibrating the measurements acquired by this instrument. However as the sensors are all reputable monitoring instruments their suitability is not an issue. The accuracy and resolution is unknown and therefore only trends and not precise readings should be compared.

# 2 Monitoring at Keyworth

Different types of monitors are housed within different locations at Keyworth. These are as follows:

| | |
|---|---|
| Monologgers: | A mobile logger which has been placed in various locations. |
| | Core store extension. |
| | Pallet store within the core store. |
| | Tray store within the core store. |
| Thermohygrographs: | Ground floor of museum. |
| | Main area of the core store. |
| Casella 500+: | First floor of museum. |
| Stevenson Screen: | Outside of main entrance of Keyworth |

## 2.1 CALIBRATION DATA

All the environmental monitors used at Keyworth have been initially calibrated at different times. It was decided in order for the data to be constant, that they all should be re-calibrated at the same time. Sending the loggers back to the manufacturers for re-calibration would be too costly and so it was decided that they should be calibrated 'in house'.

### 2.1.1 Calibration Method

All of the mobile loggers, which include four monologgers, and two hygrographs, were placed in the same location for 48 hours, commencing on the 25 November 2003. The reason why such a short period was given for calibration was that vital data would be lost from the other storage areas. A location was selected where there were variations in temperature and humidity, the main area of the core store was chosen. The raw data was downloaded from these loggers, together with the Casella 500+, which couldn’t be calibrated at the same time, as it was less mobile. These were then tabulated into excel and graphed. (See Figure 1)

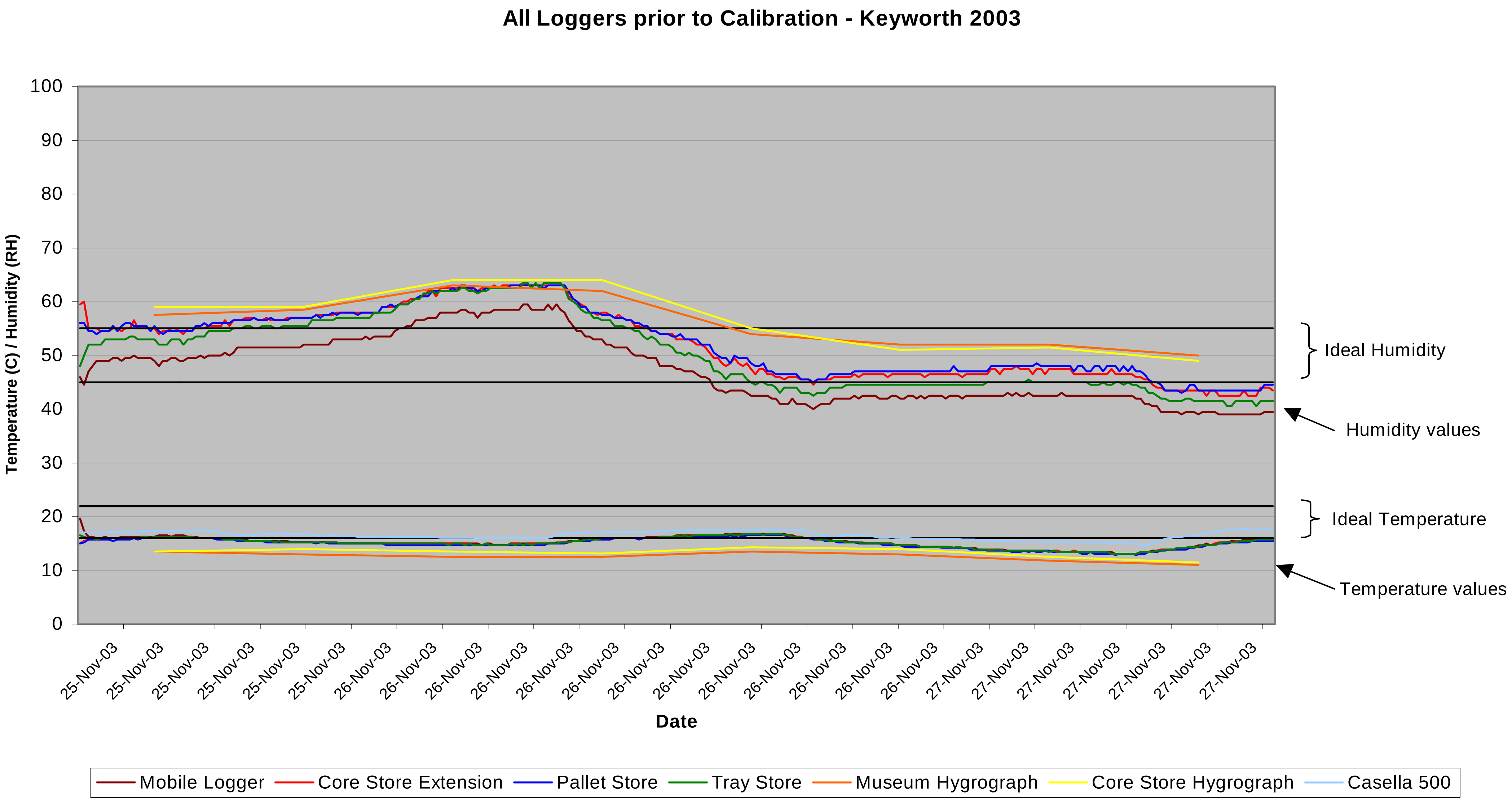


**Figure 1: All Loggers Prior to Calibration Period– Keyworth 2003**

The layout of the graph is as follows; the temperature readings are situated towards the bottom of the vertical axis with the ideal temperature ranges of 16-22°C indicated by solid black horizontal lines. The humidity readings are positioned above the temperature values; the ideal humidity ranges of 45-55% indicated in the same manner as the temperature. This layout applies to all the line graphs within this report.

The graph shows that all the monitors are producing different values, even though they are in the same locality, except for the Casella 500+, which was located in the museum.

Over this two-day period there isn't much variation in temperature, but they are almost all within the recommended temperature range. However, there is a variation in humidity, showing a gradual decrease over the two days, with some of the loggers being within the acceptable humidity range.

Based on this graph and the data it was then a case of calibrating most of the loggers so that the values were within the recommended parameters. All of the monologgers were constant and often within the temperature range, so it was decided to base the calibration data on these. For the humidity, the two loggers that appeared to be within the parameters whilst the readings weren't fluctuating were the core store extension and pallet store loggers. The humidity readings were based on these.

All of the readings from all of the loggers over this 'calibration' period were averaged. The loggers that were going to be used as benchmarks for the calibration exercise were averaged as a group. Based on all the monologgers for the temperature and the core store extension and pallet store loggers for the humidity, the remaining loggers were calibrated on these values. Table 2 summaries the calibration values.

| Logger | Average Temperature | Adjustments | Average Humidity | Adjustments |
|---|---|---|---|---|
| Mobile Logger | 15.2 | Nil | 47.4 | +5.0% |
| Core Store Extension | 15.1 | Nil | 52.2 | Nil |
| Pallet Store | 15 | Nil | 52.5 | Nil |
| Tray Store | 15.2 | Nil | 50.6 | +1.8% |
| Museum Hygrograph | 12.6 | +2.5°C | 56.1 | -3.7% |
| Core Store Hygrograph | 13.3 | +1.8°C | 56.6 | -4.2% |
| Casella 500 | 16.5 | -1.4°C | No sensor | n/a |
| Averaged calibration temeperature values based on Mobile, Core Store Extension, Pallet Store and Tray Store Loggers | | | 15.1°C | |
| Averaged calibration humidity values based on Pallet Store and Core Store Extension Loggers | | | 52.4% | |

**Table 2: Summary of Calibration Data - Keyworth**

All of the data for this calibration period was adjusted automatically using a macro in Microsoft Excel. This newly 'amended' data was then re-graphed to show all the monitors readings in a calibrated state. (See Figure 2). This now shows that all of the monitors for both temperature and humidity are all calibrated together.

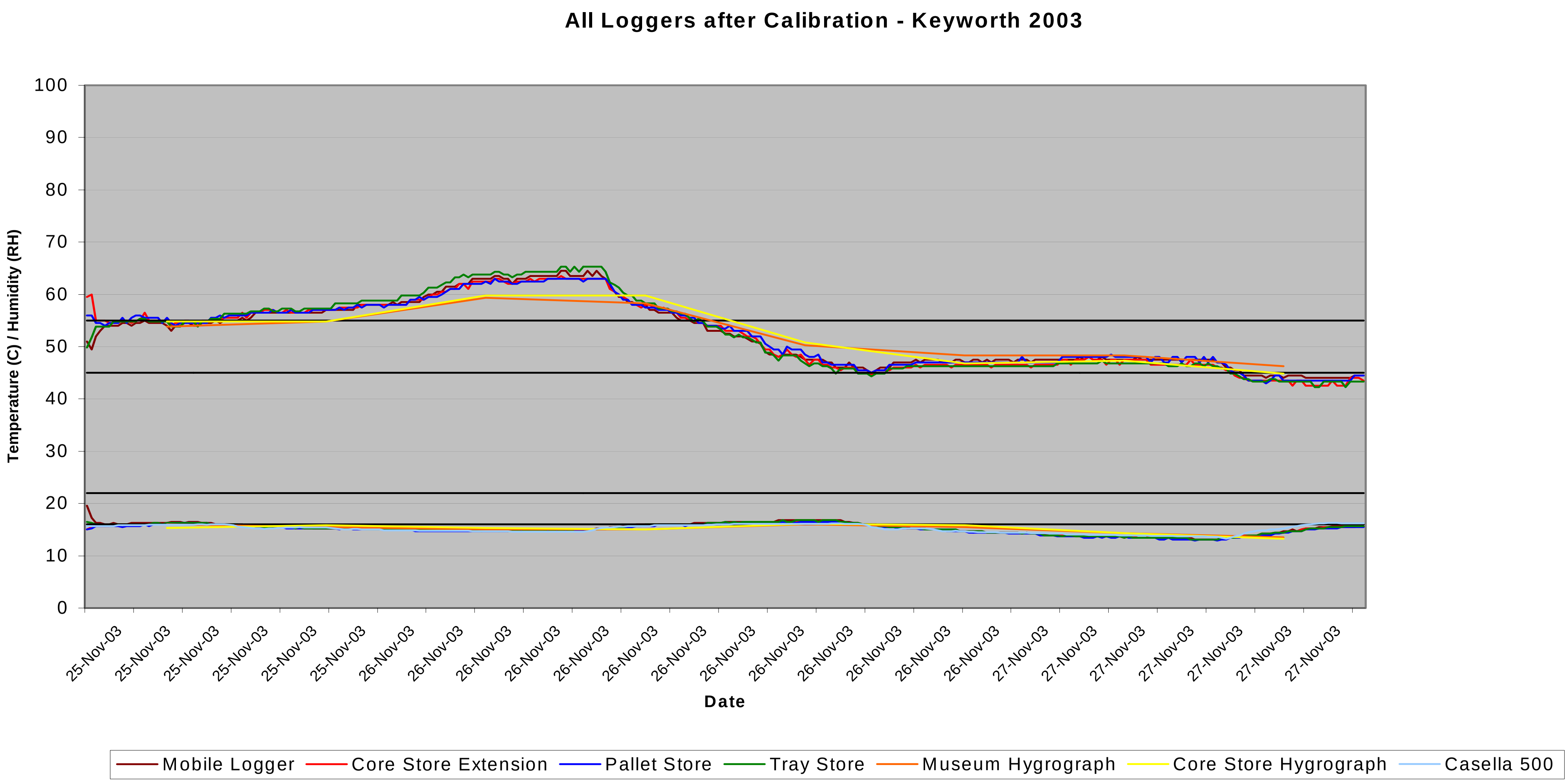


**Figure 2: All Loggers after Calibration Period - Keyworth 2003**

### 2.1.2 Calibration Summary

From this calibration experiment it was quite surprising to see how much variation in temperature and humidity occurred between the monitors, especially ones of the same type, even though they were all situated in the same location.

This justifies why all of the environmental monitors should be calibrated together on a regular basis. This then allows us to obtain a more accurate understanding of the climatic changes within the storage areas. More accurate comparisons can then be made between different storage areas in the same time period.

The ‘in-house’ calibration method used at Keyworth may not be as accurate as re-calibrations carried out by the monitors manufactures. However, at some point professional calibrations should be under taken. This would provide us with more accurate results thus helping us to monitor and improve the conditions within the collections.

## 2.2 DATA EXTRACTION

All of the data for this report was downloaded from its original format and saved in the form of .dat (Data) files for the Casella 500+ and .lcf files for the monologs. These file extensions are used in order to view the data on the relative loggers software. This data was then converted into a .csv file format to be imported into Microsoft Excel. Visual extracted readings from the thermohygrographs and weather readings from the weather station were entered directly into Excel.

The raw data had to be converted into a GMT format as the monologgers and Casella 500 had been downloaded onto computers, which took into account daylight saving hours or BST (British Summer Time).

All the data was calibrated where necessary, using a calibration macro in Excel. From this the data was filtered using Excel to show readings to the nearest 30 minutes or in the case of the hygrographs, every six hours and every 24 hours for the weather station.

This new data was then used to generate the graphs in Excel.

Please note: all data for this report can be found on a compact disk attached to this report.

The layout of the data will be in the following format:

- All raw unformatted data (lcf format) will be presented in folders for each type of monitor, for each year. Raw data will be presented in a .csv format (readable by MS Excel).
- Data used for calibration purposes will be in a sub folder.
- The thirty minute extracted, calibrated data used for yearly graphs, will be presented in folders for each year. The yearly histogram data is also included.

## 2.3 YEARLY CALIBRATED RESULTS 2002-2003

The main objective for Keyworth is to routinely monitor temperature and humidity, within the storage areas of the collections. This has been continuing at Keyworth for the last two years, together with a portion in 2001.

Three monologgers have been located in the pallet store, core store extension and tray store, which are all located within the core store. The pallet store has six aisles containing the Borehole Collection. See Plate 6. A logger has been placed in the second aisle, about a third of the way down, two metres above the ground. The position of this logger should give us an indication of the climatic conditions that can develop in these confined spaces between the aisles.

**Plate 6: The Pallet Store.**

The core store extension was officially opened in November 2002 and houses over 20km of continuous drill core from boreholes originally collected to examine the suitability of the ground conditions to locate an underground repository for radioactive material. This area is currently approximately a quarter full. This logger is located at the end of the first fully filled rack. It was decided to place the logger between a full aisle and the open section of the core store extension where there should be the maximum variation in readings between each of these two areas. See Plate 7.

**Plate 7: The Core Store Extension**

The tray store has twenty-two aisles on four levels; the first two levels hold registered samples and chippings from a variety of boreholes. See Plate 8. The third and part of the fourth level contains the Palaeontological specimens, whilst the remainder of the fourth level contains the Petrological Collection. The specimens in the tray store are stored in either a lidded wooden, plastic or cardboard tray. A logger is positioned on the top floor, 77cms above that floor level and adjacent to the main open area of the core store, which is approximately 7.5 metres below. This would hopefully show any variation in temperature and humidity between the confined areas of the tray racking and the open void of the main core store area. The heating within in the core store is based on an air blown system that is set to keep to the temperature above the dew point. On each level of the tray store there are vents that direct air between each aisle. A series of radiators are also situated around the edge of the core store extension and the main area of the core store.

**Plate 8: The Tray Store.**

Each of these monologgers were recording on two minute intervals up until 23 December 2002 when they were changed to read at three minute intervals. This change was to reduce the number of readings to download each week and to make the number of readings consistent with Murchison House. Even at three-minute intervals, any sudden changes in temperature and humidity would still be noticed.

Two thermohygrographs have been located in the main area of the core store, and on the ground floor of the museum. A monitor is located in the main area of the core store at ground level. This should show any variations between the pallet store and the fourth floor of the tray store. The monitor in the museum is situated against a run of wall cabinets, away from any doors or windows where changes in air movement and solar radiation respectively might affect the readings.

The Casella 500+ is located on the top floor of the museum, on the corner of a workbench that runs the along the southeast facing wall of the museum. The heating system in the museum consists of radiators on each floor together with an air circulation system, which draws air in from the outside and heats it up to the desired temperature. There is also an extraction system, which extracts the air from within the museum. See Plate 9.

**Plate 9: The Museum.**

### 2.3.1 Yearly Calibrated Results

Yearly graphs have been generated for all of the loggers for a specific year, i.e. 2003 and 2002, with corresponding acetate overlay displaying external climate conditions for that relevant year. These graphs show trends throughout the year plus any changes in temperature and relative humidity.

The yearly graph for all the Calibrated Monitors in 2003 is shown in Figure 4.

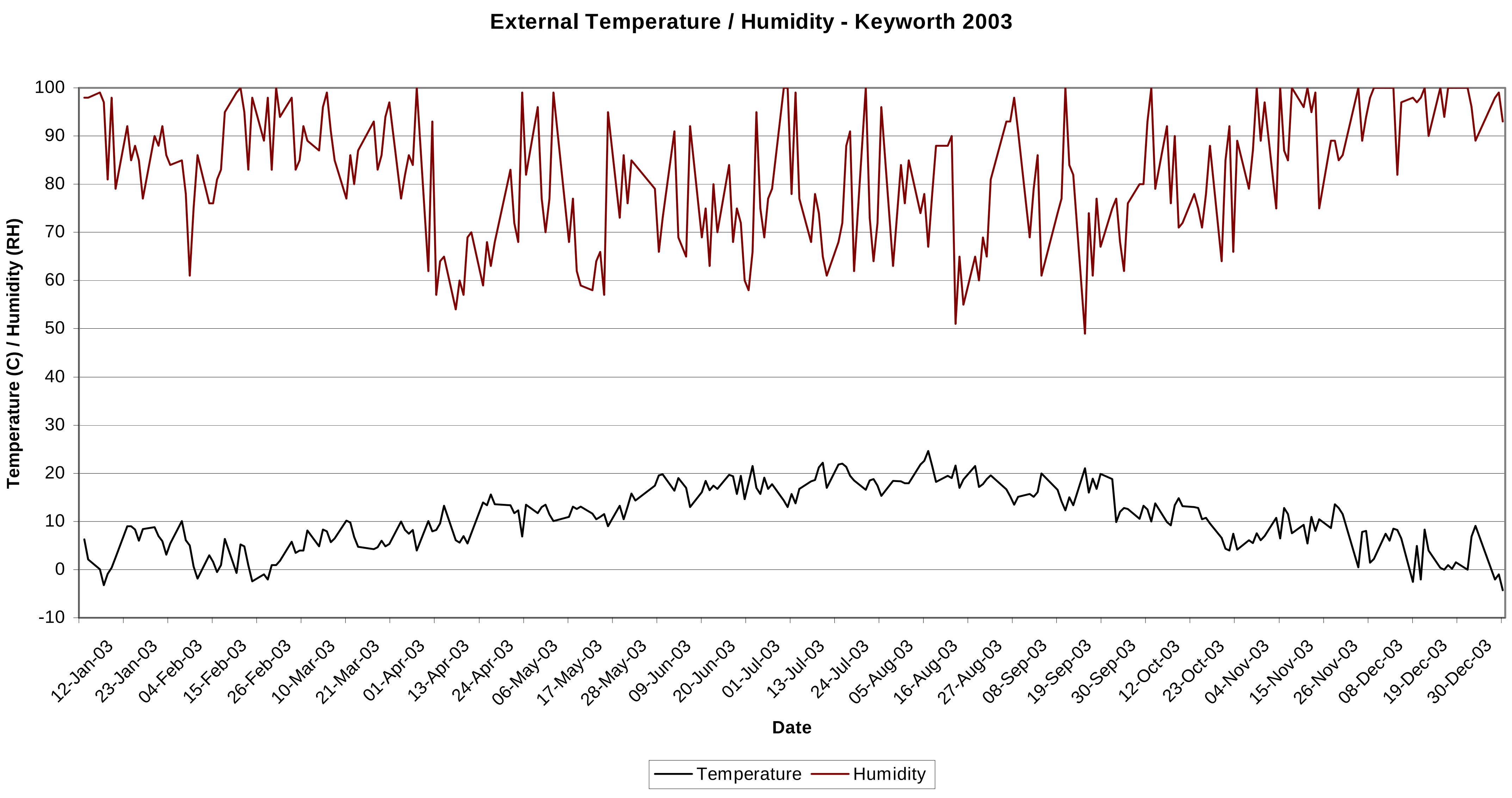


**Figure 3: External Temperature / Humidity - Keyworth 2003**

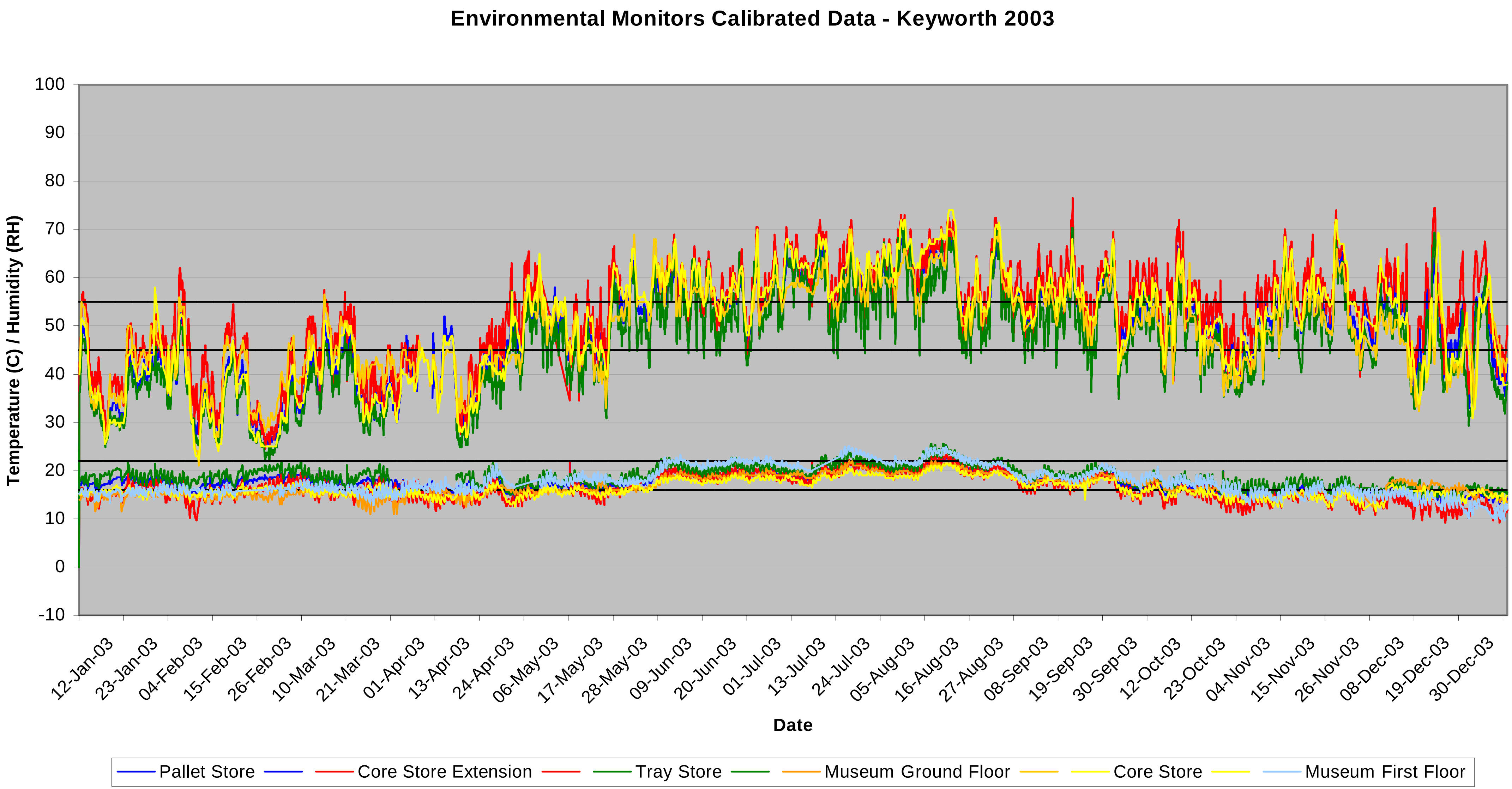


**Figure 4: Yearly readings from Environmental Monitors - Keyworth 2003**

The results from Figure 4 show that there are major variations in humidity throughout the year 2003, for all the localities mentioned. However the temperature ranges are more stable with slight variations of about 10°C.

From January through to mid April the humidity readings are dramatically below the recommended ranges, other than a few regular periods that appear within the 45-55% range. The core store and tray store appear to have the lowest readings whilst the core store extension has the highest values. The temperature values to mid April are all within 16-22°C except for the core store extension and the ground floor of the museum. These have the lowest readings of all the locations and the majority of the time these dip below 16°C. On several occasions towards the end of January the temperature for the core store extension falls to 10°C where condensation may occur thus affecting the condition of the material stored within.

From mid April through to the end of the year there is a switch where the humidity has increased, on average to 55%. On numerous occasions the localities have exceeded this value and peak at around 75%. The core store extension and the main area of the core store have produced the highest readings. The tray store has produced the lowest and most acceptable readings for humidity. Such high and low values in humidity can aid in the development of conditions that then can damage certain types materials. Periods of high humidity can cause pyrite decay, deliquescence, or deformation through the absorption of moisture. Low humidity environments can aid with the onset of efflorescence and the shrinkage of shale and sub fossil bone. *Child* (1994).

The temperature readings from mid April through to the end of September, for all of the monitors, except for the museum first floor, which is slightly higher, appear to be within the acceptable parameters. From September through to the end of 2003, all of the temperature readings gradually decrease below 16°C, expect for the tray store and ground floor museum, which hover just above the minimum recommended value.

If the acetate for the external temperature and humidity, Figure 3, is placed over Figure 4 comparisons can be made between the internal and external environments. From both graphs it can be seen that there is a slight increase in the temperature internally as the temperature externally rises gradually through to mid May. Through the summer, from mid May until the end of September, the internal temperatures seem to track the external conditions. During this period the temperature recorded at 9:00 (GMT) rose to 24.6°C on the 6 August 2003. As temperatures continue to rise throughout the day internal temperatures are affected. After September, as the external temperature decreases, the internal values do not track these in the same manner, but start to fall more gradually to about 15°C, just below the recommended parameters for temperature.

The external humidity throughout the year appears to be affected by the external temperature. This remains in the 80’s to 100% until the temperature exceeds 12°C; this then averages out to about 75%. When the external temperature drops below 12°C the humidity then starts to climb. It is presently inconclusive as to whether the external humidity is having an affect on the readings taken internally. There are only a couple of instances where internal humidity readings track those of outside. These occur at the beginning of February and between the 1st and 13th of April 2003 where substantial drops in external relative humidity readings occur.

The graph for all the Calibrated Monitors in 2002 is shown in Figure 6.

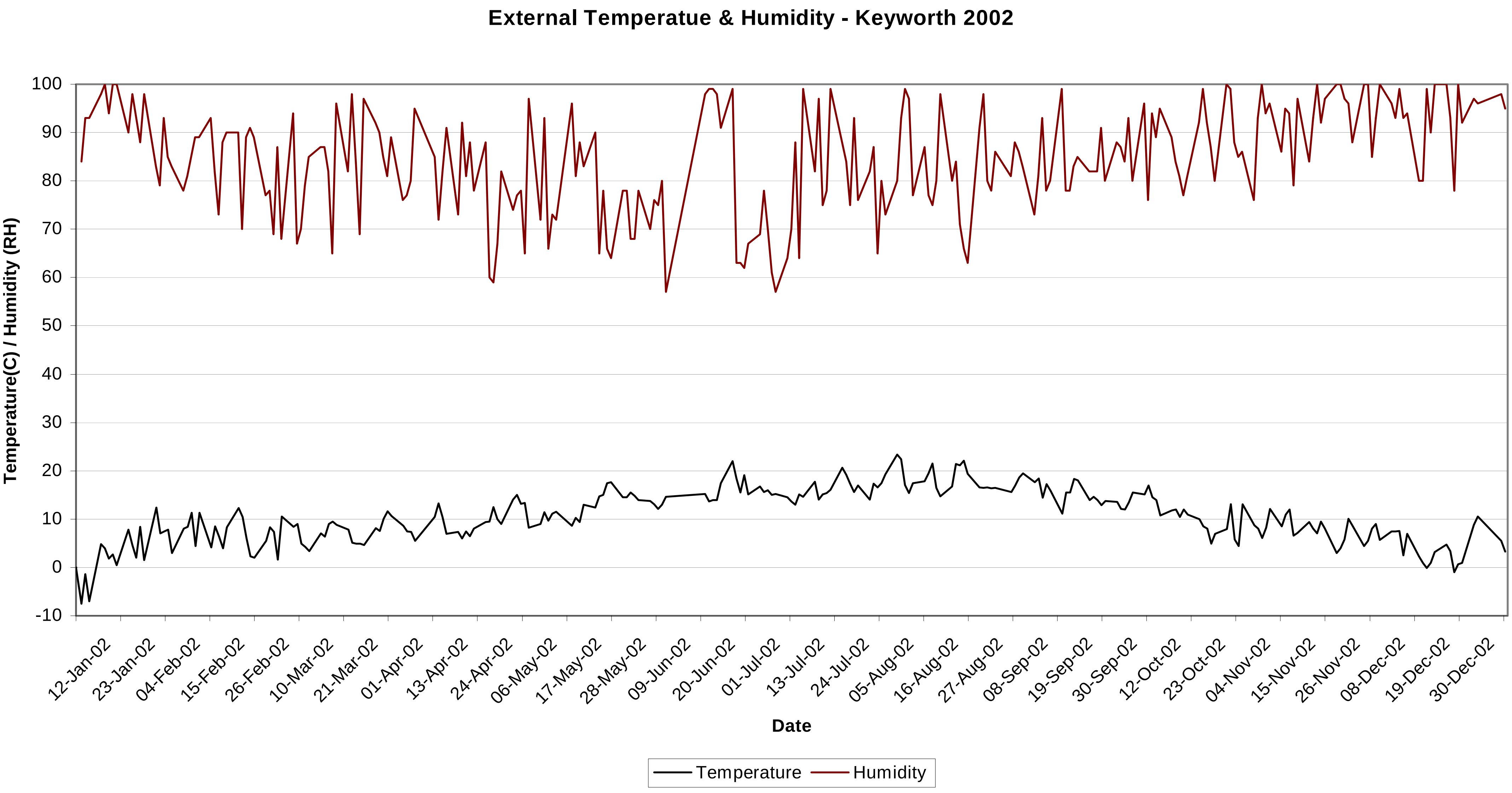


**Figure 5: External Temperature and Humidity - Keyworth 2002**

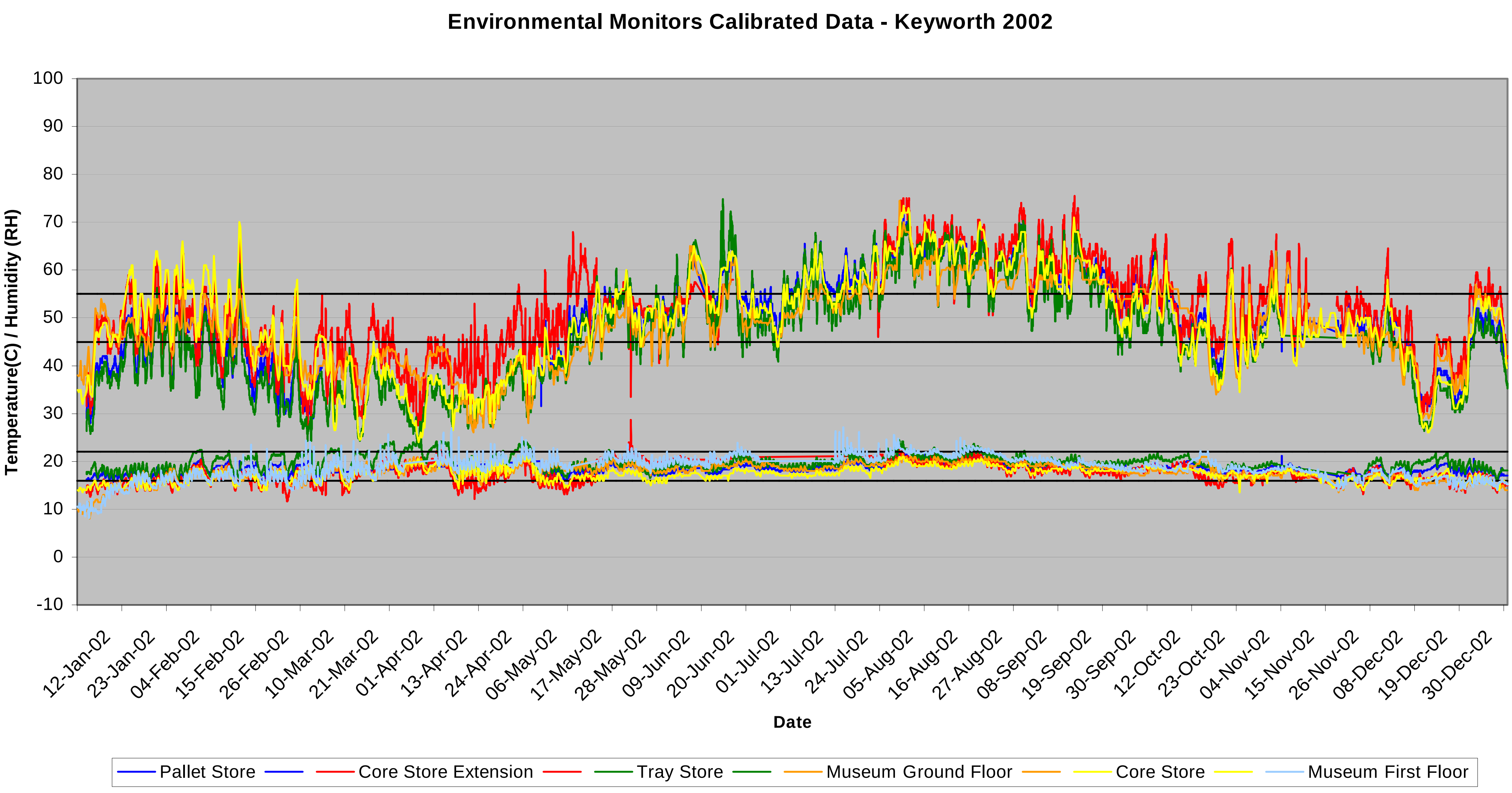


**Figure 6: Yearly readings from Environmental Monitors - Keyworth 2002**

Readings from 2002 have also been examined. These show a similar trend as 2003 where the temperature readings are within 16-22°C. The winter months show a drop in readings below 16°C except in the tray store and part of the time in the first floor of the museum. During the summer all of the monitors are within the ideal temperature range except for a couple peaks reaching 25°C on the first floor of the museum. It is likely that the peak associated with the core store extension, around the 21st May 2002, is an irregular value as this does not appear on any of the other loggers within the Core Store.

Fluctuating trends in humidity for 2002 are very similar to those of 2003. From the beginning of the year to the end of February 2002 there is a sudden increase to about 55%. This is followed by a gradual decline to around 40%. During this time frame the core store has the highest readings whilst the Tray Store has the lowest values. All of the humidity readings begin to increase once again from the 1st April through to mid May, where they start to level off at around 50%. During this short period the core store humidity is one of the lower values whilst in the month prior this was showing the highest of all of the readings. Throughout the summer until the end of September the humidity remains high averaging at 65% with upper values reaching 75%. For the remainder of the year the humidity starts to decrease. This then suddenly drops around the beginning and middle of December to 25%.

If the acetate showing the external temperature and humidity for 2002, Figure 5, is placed over Figure 6 comparisons between the internal and external readings can be made. As the external temperature gradually increases through the year to mid May the internal loggers are showing a similar pattern. Major peaks in external temperatures are tracked by the internal values especially through April. During May there is a single elevated peak in the core store extension. This is not represented by any increases in the external weather and therefore this may be due to an irregular reading on the monitor concerned. Throughout the summer months the tracking temperatures are not as noticeable as 2003 however, the high values within the first floor of the museum track the high peaks for the external temperature. Come autumn and throughout winter the external temperature begins to fall, as in 2003. The internal temperatures also begin to follow this pattern. This however isn't as pronounced as we saw in 2003 probably because the external temperatures did not drop to 0°C as frequently. A sudden drop in temperature registered on the first floor museum monitor coincided with a sudden decline in the temperature measured at the weather station in January 2004 where temperatures fell to -8°C.

For the humidity, there is no major trend where the external humidity has an effect on the humidity inside. There are a couple of instances where the humidity recorded at the weather station suddenly rises and the internal monitors also record an increase to about 65%. This occurred from the beginning to the middle of June and also again through August. This may be due to an extent by the opening of windows allowing hot, humid air from outside, as measured at the weather station, to enter the room.

#### 2.3.1.1 Comparisons of Yearly Calibrated Results

Trends for both years appear to be very similar. There are certain factors, which might contribute to such patterns within these storage areas. During the spring the inside temperature isn't affected by the low temperatures outside. This is due to the heating systems being operational within the buildings, which help to maintain a constant temperature. At this time of year there are often high amounts of precipitation. Such quantities of rainfall would lead to increased humidity levels outside. Over a period of time building materials would get wet, or even saturated, and any dampness could penetrate into the interior of the buildings as damp patches. This combined with warmer central heating temperatures during these months could increase the levels of humidity within the structure. As the year approaches May or June the central heating is usually turned off as the temperature starts to rise outside. With higher summer temperatures humidity levels often increase outside. These increases are noticeable during both years for this period. One of the main factors is due to windows being opened to make working conditions more comfortable, particularly in the museum. With doors and windows open hot, humid air can penetrate into the building and the humidity levels rise. An increase in stronger light levels over the summer would increase the temperature, for example in the museum, even though the blinds are kept down for the majority of the time.

From approximately October the heating is turned on for the winter months; this has reduced the drop in the internal temperature to a more gradual decline. External humidity levels still remain high due to wet weather conditions. If draughts around window frames are not correctly sealed this could lead to an increase in the interior humidity.

#### 2.3.1.2 Comparisons of Yearly Results through Histograms

Even though the line graphs show the trends throughout each year, they do not express as a percentage the time each area falls within, above or below the recommended parameters for temperature and humidity. The data therefore has then been shown in a histogram format which shows this more clearly.

Figure 7 shows the temperature ranges for all of the monitors in 2003 as a percentage. For at least for 50% of the time all the monitors are displaying readings within the 16-22°C parameter. However, the tray store and pallet store reach around 80%. All the monitors except one on the ground floor of the museum spend less than 10% of the time with readings above the ambient 22°C. The majority of loggers, except the pallet store and tray store, spend more than 30% of time with readings below 16°C.

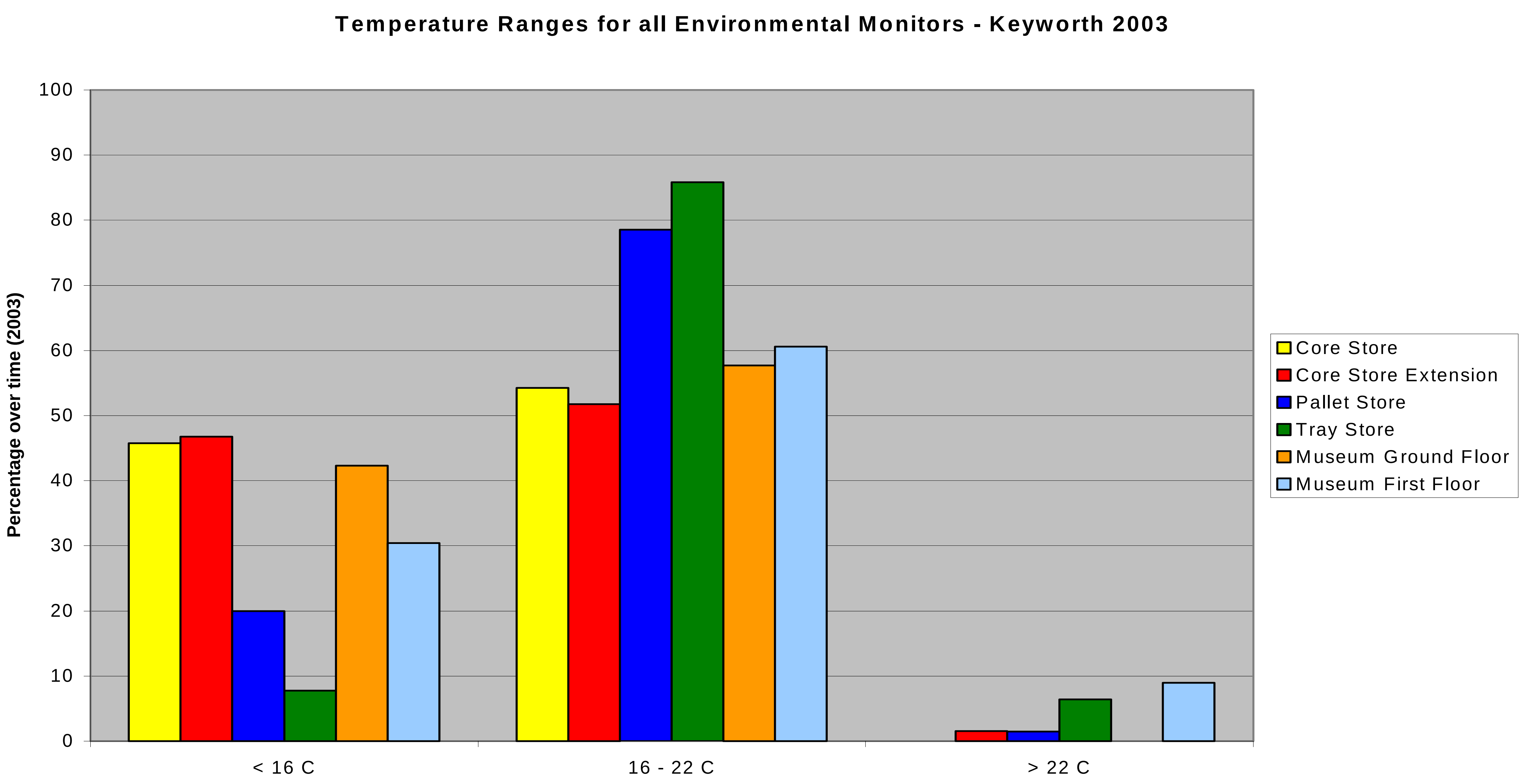


**Figure 7: A histogram showing temperature ranges for 2003 – Keyworth**

The temperature readings for 2002, Figure 8, show that 75% of readings for each monitor are within the 16-22°C storage guidelines with only a small proportion of readings being above or below recommended ranges. A major factor to cause such differences between both years is the variable temperatures recorded outside. The 2003 winter readings were lower for a longer period of time than in 2002. This would explain why there is an increase in the number of readings below 16°C. An important note is that the heating system within the museum has not been functioning properly this year. This would indicate why the percentage of lower temperature readings has increased within the museum. This problem is being investigated by the Facilities Management Team and will, hopefully, be resolved soon. An improvement within the museum temperature should then be seen. It must also be noted that the central heating over the site is turned off during the weekends. From the results there is no indication that this affects the temperature readings within the storage areas, further studies could be carried out in the future.

Similar histograms show the humidity ranges for 2003 and 2002, see Figures 9 & 10 respectively. For 2003, at least 27% of the time all of the locations are within the 45-55% parameter. This is a decrease compared to 2002, where 40% of the time all areas were within this range except for the tray store. The amount of time where humidity readings exceed the 55% parameter has increased from 2002. The core store and core store extension show the largest increases. For readings below 45%, there is no significant change between 2003 and 2002, other than a slight increase for the pallet store and tray store. This increase in humidity compared to the results from 2002 is probably due to the monitors recording more time spent below 16°C in 2003 and less time within the recommended parameters.

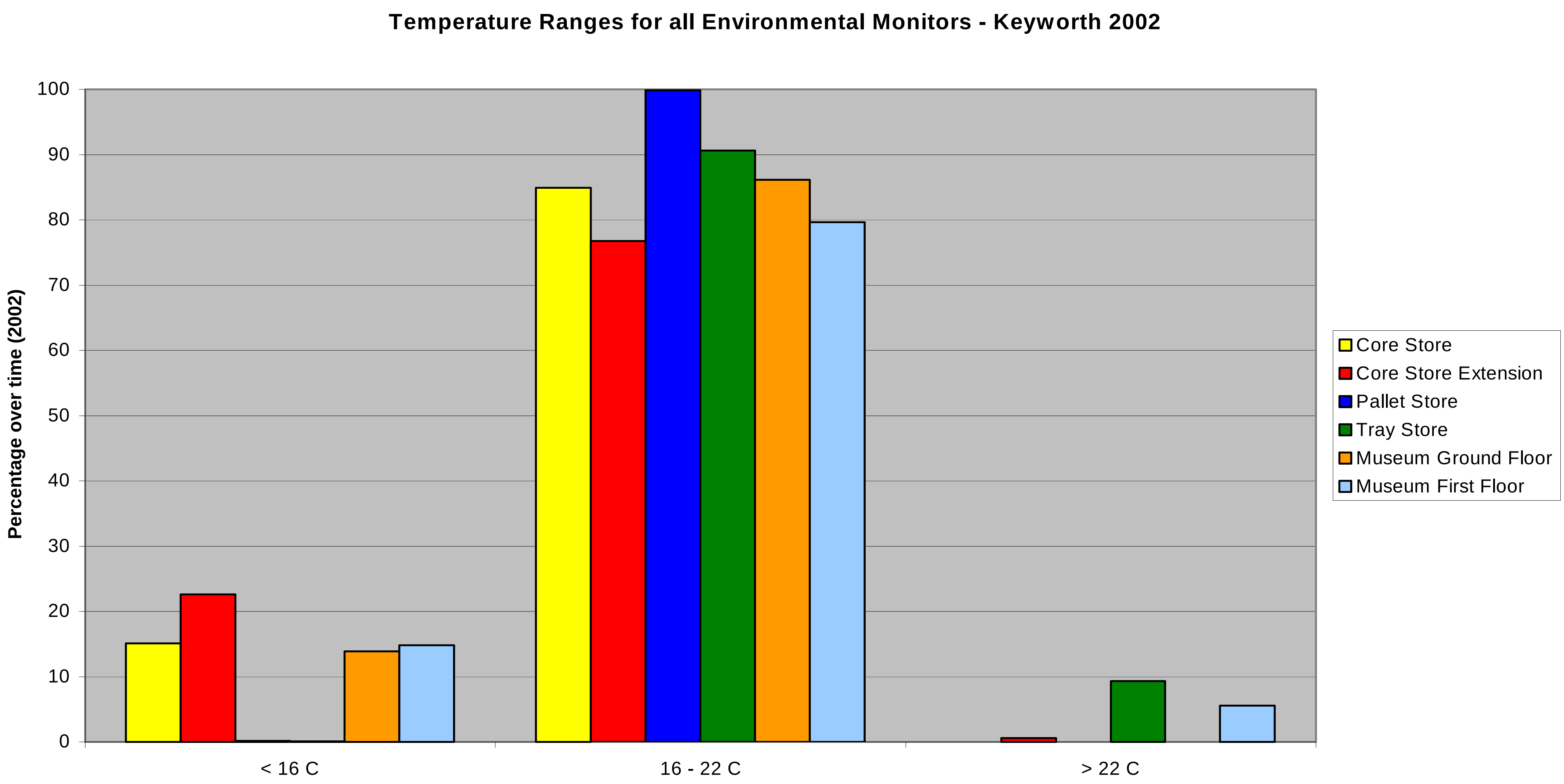


**Figure 8: A histogram showing temperature ranges for 2002 – Keyworth**

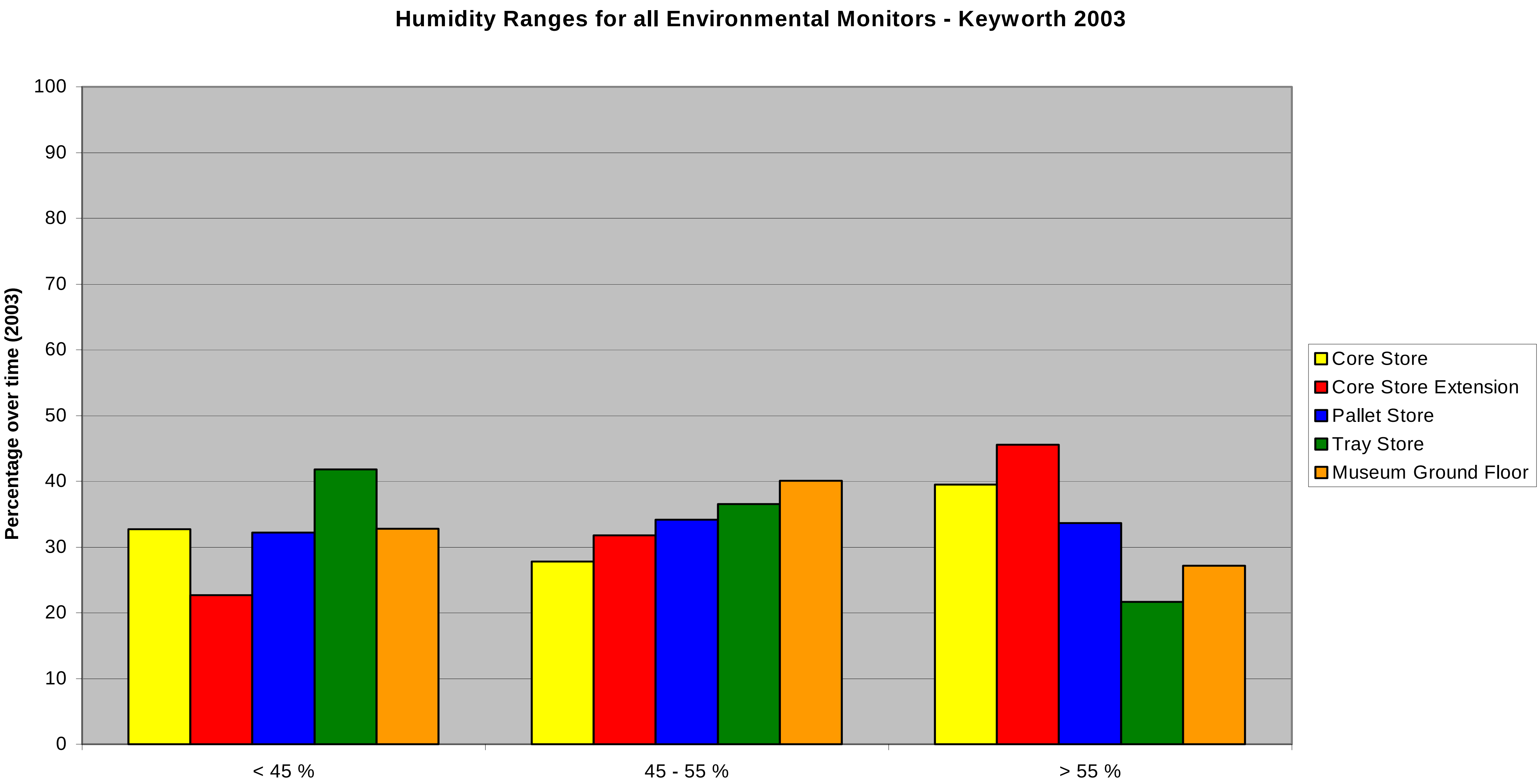


**Figure 9: A histogram showing the humidity ranges for 2003 – Keyworth**

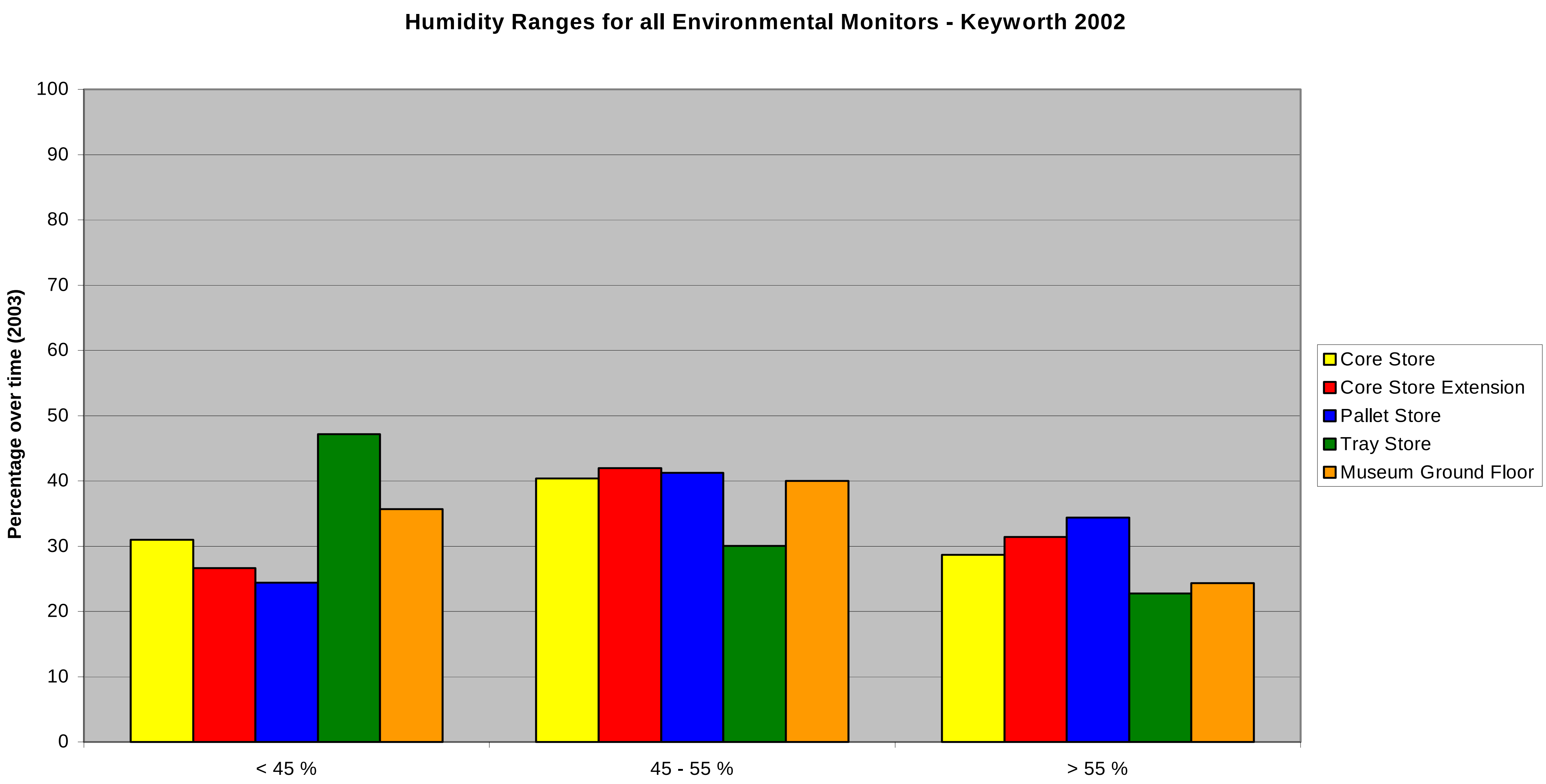


**Figure 10: A histogram showing the humidity ranges for 2002 - Keyworth**

### 2.3.2 Yearly Calibrated Summary

Within these storage areas there are gradual variation in temperature for each year. A similar pattern occurs over both 2002 and 2003. These changes seem to be affected by external temperature values. This is moderately compensated by central heating systems used within the storage areas concerned during the winter months. Trying to heat such large areas is a problem especially through the colder months. If this could be achieved affectively then I believe that the humidity would become more stable during these cooler months. Humidity levels during both years show a dramatic change throughout the seasons. Values often fall above and below the recommended parameters. Readings internally do not appear to be directly affected by external humidity. The exception to this is during periods of hot, humid weather during the summer or when precipitation levels are high. Variations in humidity outside of the parameters have increased over the last year. Such changes may be due to more extreme weather conditions, which then effect conditions internally.

Unfortunately, the results for the storage areas for both years are often not within the recommended humidity ranges. This should give us cause for concern. Therefore further monitoring needs to be implemented and recommendations put in place to avoid damage being sustained by the collections.

## 2.4 MINI PROJECTS

Further studies were taken in the form of ‘Mini Projects’ over the two years. These were to monitor the conditions in which the specimens / materials are stored. This would show any differences between the storage containers and the storage areas.

### 2.4.1 Museum Wall Cabinet & Mahogany Cabinets

For a six-week period commencing on the 4th March 2002 we decided to monitor the environmental conditions within the mahogany cabinets (See Plate 10) and wall cabinets within the museum (See Plate 11). There are 195 mahogany cabinets spread over two floors. Within each cabinet there is on average forty drawers each drawer has a tight fitting glass lid, which can be removed by sliding it off. Each cabinet has a felt strip around the edge to insure a tight seal around the frame. The cabinet doors are shut by turning a handle which can be locked with a key. The wall cabinets, which are situated around the outer walls of the museum, contain the larger specimens. There are fourteen all together, each containing adjustable shelves. There is a felt strip around the edge of the frame, and the glass doors are hinged and lockable.

The monologger situated in the pallet store was used for this project. For the first two weeks the monitor was placed in a randomly selected cabinet and, for the remaining four weeks, within a randomly selected wall cabinet, both of which are located on the ground floor. The data was initially collected every two minutes. During this period a thermohygrograph and the Casella 500 were also present on the ground and first floors of the museum, respectively. Please note; the humidity sensor on the Casella 500+ is faulty and therefore humidity values for the first floor are not included.

**Plate 10: Mahogany Cabinets** **Plate 11: Wall Cabinets.**

2.4.1.1 MUSEUM WALL CABINET & MAHOGANY CABINET RESULTS

From Figure 11, it can be seen that the temperature within the mahogany cabinets (blue line), varies slightly throughout the experiment but the readings fall within the acceptable temperature parameters. Daily temperatures fluctuate on both floors of the museum, except for a few sudden increases in temperature. The values do fall within 16-22°C parameter but are not as stable as the results from within the mahogany cabinet.

Once the monologger is placed within the drawer of the cabinet and humidity levels settle they appear to remain constant at 45%. The humidity on the ground floor fluctuates between 43% and 34%. The monitor within the cabinet is not picking up these changes.

The monitoring of the museum wall cabinets, which began on 18th March have also shown surprising results. The temperature within the wall cabinets stays constantly within 16-22°C and only changes gradually. Whereas in the museum, variations are more pronounced with more peaks appearing above 22°C on a daily basis. The humidity readings, after yet another settling down period, show similar effects as the drawers in the mahogany cabinets. This time the readings are constant, but about 5% lower. Outside the wall cabinet the readings are constantly changing, especially from the 9th April where the humidity values are fluctuating rapidly on a daily basis. These appear to track the humidity values of outside.

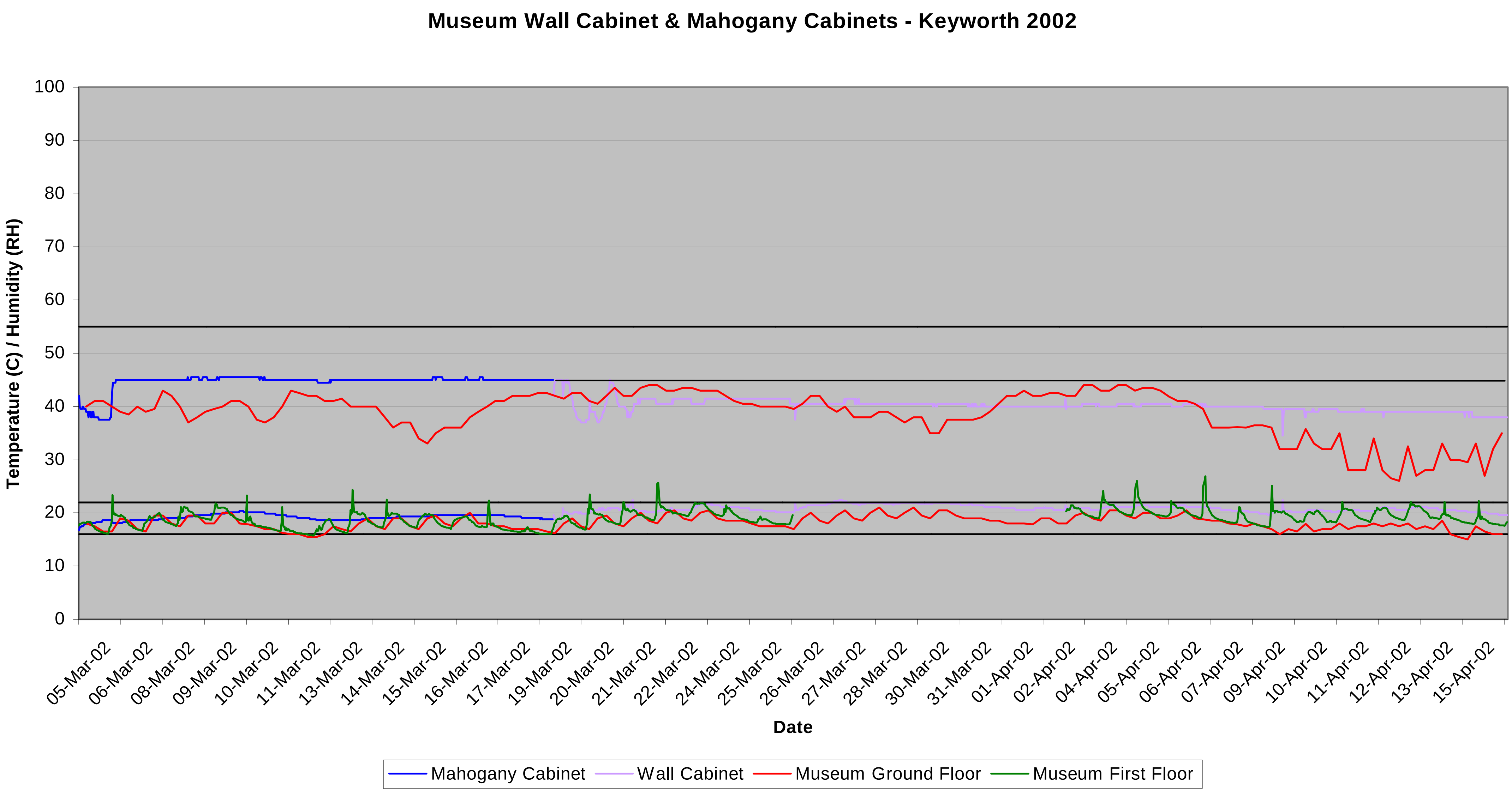


**Figure 11: Temperature and humidity levels within Museum wall & Mahogany cabinets**

#### 2.4.1.2 Museum Wall Cabinet & Mahogany Cabinet Summary

In summary, it can be seen that both the museum wall cabinets and mahogany cabinets are showing stable values even though the environment in which they are stored records fluctuating temperature and humidity levels. These sudden or rapid changes can cause severe damage to specimens and, therefore, should be avoided. Conversely, conditions within the cabinets are ideal as the cabinets buffer the effects from the museum before reaching the specimens. The wall cabinets are perform a similar job even though only one pain of glass separates the specimens from the environment conditions within the museum.

### 2.4.2 Museum Cabinets (100/39 & 69/27)

A further study was carried out on two museum mahogany cabinets with two different contents. This was investigated from 10th February to 12th May 2003. The 'mobile' monologger was used whilst background readings on the ground and first floor of the museum were recorded on the thermohygrograph and the Casella 500+ respectively. Please note, the humidity sensor on the Casella 500+ is faulty, and therefore humidity values for the first floor are not included.

The mahogany drawer (100/39), which contained Ammonites from the Upper (Lias) Jurassic, was chosen on the first floor of the museum. For the second investigation a mahogany drawer (69/27) had been removed whilst on loan so the monitor was place in this void. This cabinet contained Amphibia from the Carboniferous coal measures. This study shows us the conditions in a sealed mahogany drawer within the cabinet compared to the void within the cabinet just leaving the cabinet doors locked.

#### 2.4.2.1 Museum Cabinets (100/39 & 69/27) Results

A graph displaying the results for both of the cabinets is shown in Figure 12.

The monitor situated within drawer 100/39 shows a generally constant temperature within the 16-22°C range. The temperature within the cabinet follows a similar trend to those recorded on both floors of the museum, however the museum temperature is slightly lower.

During this period, 10th February until 10th March 2003, the ground floor humidity varies from 28% through to 57% with only a small proportion of readings recorded in this time falling within the recommended parameters. In comparison, the readings from the monitor placed in drawer 100/39 are constant even though they are a few percent below the minimum recommended value.

From 14thApril to 12th May the results of the void area for drawer 69/27 show similar readings as drawer 100/39. The temperature is stable and within the parameters except for a brief period of irregular results. The humidity values are generally steady around 40% these appear to be slightly lower than those from drawer 100/39. There is, however, slight variation in the humidity readings, of about 5%, that do not appear in drawer 100/39 whilst the humidity within the museum fluctuates between 40% and 60%.

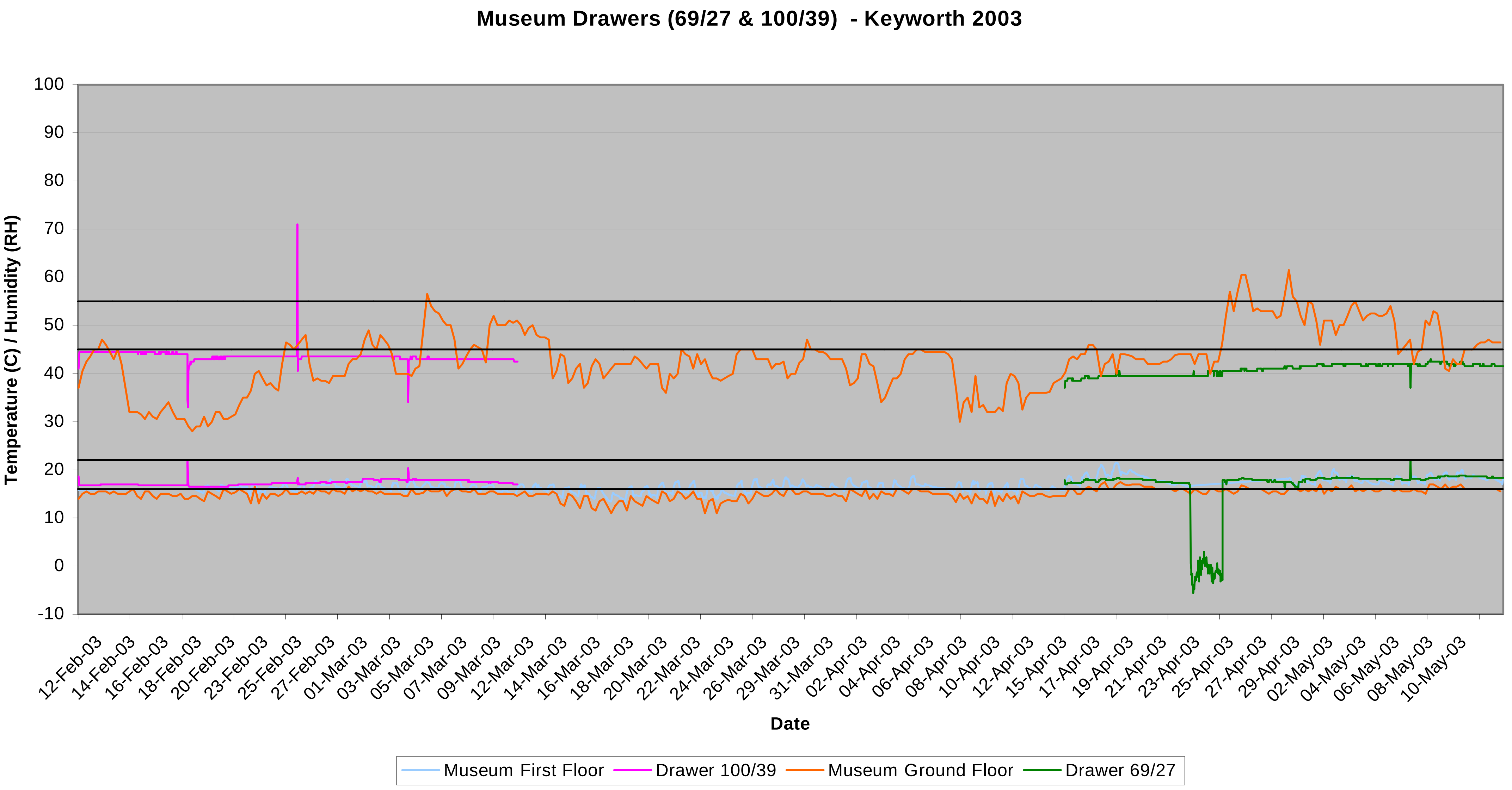


**Figure 12: Temperature and humidity within Museum cabinets**

2.4.2.2 MUSEUM CABINETS (100/39 & 69/27) SUMMARY

Both of the cabinet drawers used in this experiment show constant, yet different, humidity readings compared to those from the museum, which fluctuate between 30 and 60%. For drawer 100/39 the cabinet doors and the glass lid of the drawer protect the specimens. These readings are constant, yet slightly higher than those from the void of drawer 69/27. The values from the space left by drawer 69/27 should not be dismissed as ineffective as the mahogany cabinets' doors are acting as a buffer from the humidity ranges being experienced within the museum. The temperature readings are also constant for both drawers and are within the acceptable parameters, whereas the museum readings on both floors are generally lower and outside the parameters. Based on the ambient humidity ranges of 45-55% this emphasises that the specimens appear not be subjected to erratic variations in humidity within the museum. That is why in comparison the conditions within the cabinets are better suited to the storage of these specimens.

### 2.4.3 Wooden Tray in the Tray Store

Mini projects have been carried out in the storage cabinets within the museum so it was decided to monitor the conditions for samples held within the tray store. This would hopefully show us any differences between the storage containers and their surrounding environment. The monitoring exercise was carried out between the 4th and 11th November 2003. The tray (23133) was randomly chosen. It is situated on the fourth floor of the tray store amongst the Palaeontological collection. This deep wooden lidded tray contains large chalk samples collected from Beer, Nr. Sidmouth, Devon, of the Upper Cretaceous period. See Plate 12. The monologger used was from the tray store area so no information will be available on the surrounding location but instead comparisons can be made from readings taken from the thermohygrograph in the main area of the core store.

**Plate 12: Wooden Tray in the Tray Store.**

#### 2.4.3.1 Wooden Tray Results

From the graph shown in Figure 13, the temperature within the wooden tray (red line) is as constant as the temperature within the main area of the core store (green line). Both values are within the 16-22°C parameter. The humidity readings from within the tray are constant at around 47%, which is also within the parameters, while the humidity within the core store area is fluctuating throughout the experiment with periods of time outside of the 45-55% parameter. It must be noted that the results on this graph appear differently in comparison to those on other mini projects. This is because the data from the thermohygrograph, and the monologger, are extracted every six hours and 30 minutes respectively.

#### 2.4.3.2 Wooden Tray Summary

From the results gathered it can be seen that the tray is buffering any conditions that are being experienced within the tray store. This is especially noticeable on the humidity readings within the wooden tray. This type of sealed container provides suitable storage conditions for the type of material requiring parameters of 16-22°C and 45-55%.

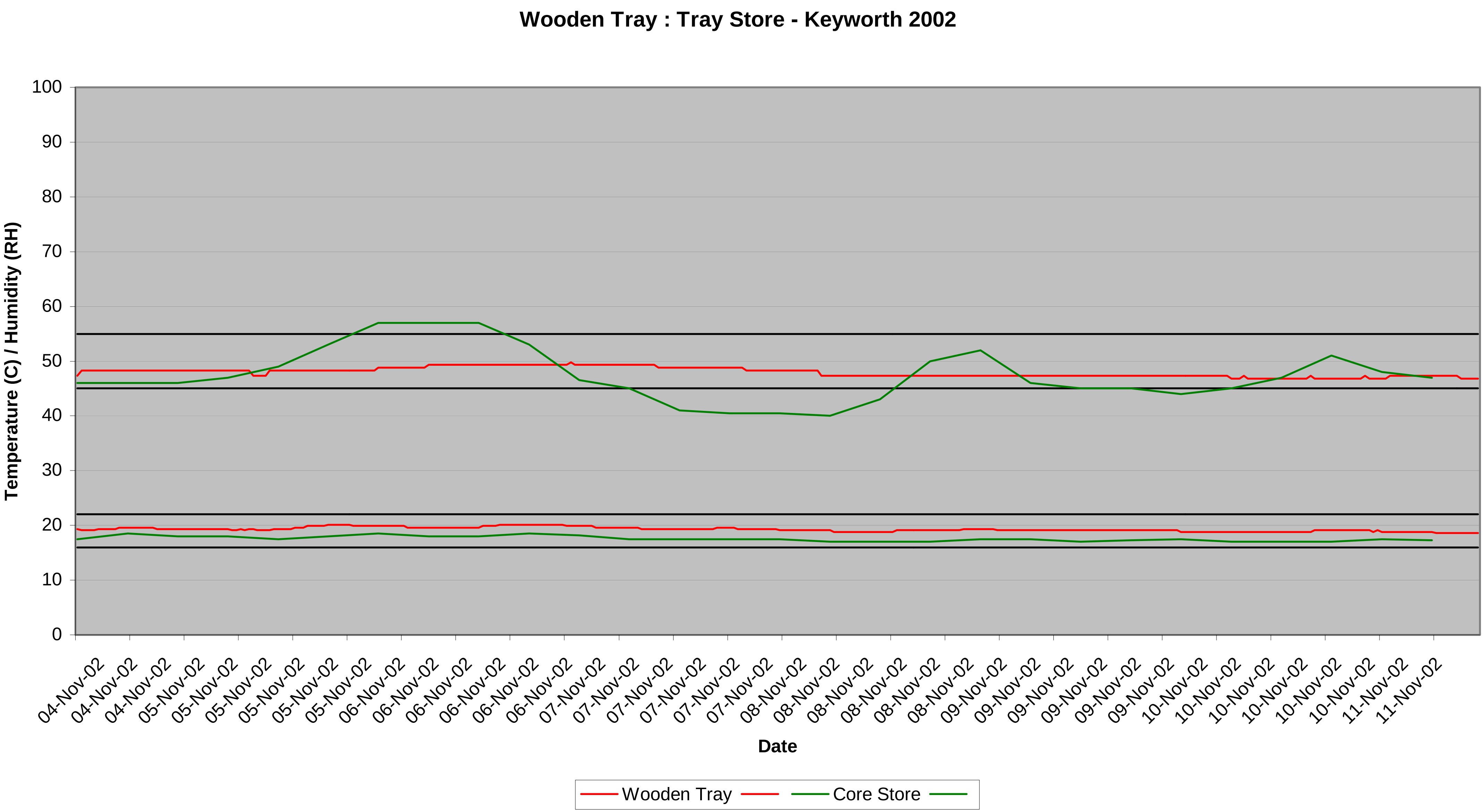


**Figure 13: Temperature and humidity within a wooden tray**

### 2.4.4 Desiccator & Laboratory

The preservation of the collections is vitally important. One of the most damaging effects to any collection is the onset of pyrite decay through a process of sulphide oxidation. If specimens are not monitored for this condition the total destruction of many important specimens may occur. Once pyrite decay has been identified through certain signs, such as efflorescence, cracking within the specimen, an acidic smell and scorching of the packaging, then treatment for pyrite decay must commence. To arrest further development of pyrite decay the specimen must first be chemically treated for this potentially damaging condition. After treatment the material should be stored in a conditioned microclimate, ideally at 30%. *Child (1994)*. Before a specimen is placed within a microclimate it should be stabilised to the preferred humidity. The procedure is performed within a desiccator; orange indicating Silica Gel is used for this process.

It would be useful to monitor the conditions where specimens requiring conservation are being worked upon including within the desiccator. The monologger from the core store extension was used for this experiment and was initially placed in the desiccator from 17th June 2002 until 1st July 2002. See Plate 13. This is situated in the fume cupboard in the laboratory. The monitor was then removed from desiccator and placed in the main area of the laboratory, until 22nd July 2002. See Plate 14. Readings were initially taken at two-minute intervals. The laboratory is situated opposite the core store extension and has no windows or central heating. The only ventilation is via the sliding door into the core store reception area and through the fume cupboard.

**Plate 13: Desiccator in the Laboratory.**

**Plate 14: The Conservation Laboratory.**

#### 2.4.4.1 DESICCATOR & LABORATORY RESULTS

The graph in Figure 14 shows the readings recorded for both temperature and humidity levels in the laboratory and desiccator. Temperature readings for both these areas were almost constantly within the upper recommended limits of 22°C. The humidity values from within the desiccator have shown some interesting results. The monitor was left in the laboratory for four days where the readings show humidity levels between 64% and 38%. The monitor was then placed in the desiccator which contained five grams of Silica Gel. The data shows that there is a dramatic fall in humidity levels from 52.5% to 23%. The decrease looks instantaneous but in fact occurred ‘quickly’ over an 18-hour period. From this point there are a few increases of 5% but then the monitor records levels of around 28%. This slow increase could be caused by the Silica Gel becoming more saturated and gradually less effective.

The monologger was then placed on a shelf in the laboratory and left until the 22nd July 2002. The humidity readings for this period show values around 55%, although there are some additional drops in humidity, which are similar to those recorded at the beginning of this experiment. Having looked at the data for these periods this coincides with occupancy patterns within the laboratory or the use of the fume cupboard.

#### 2.4.4.2 Desiccator & Laboratory summary

The results show that the desiccator with the Silica Gel is performing well. The readings are stable and are ideal for the initial treatment of pyrite decay. The laboratory is also producing stable values, which are suitable for the storage of specimens, such as sub-fossil bone, and fossils within a clay or shale matrix, whilst they are being conserved. Patterns of occupancy need to be monitored in the future to eliminate sudden drops in humidity.

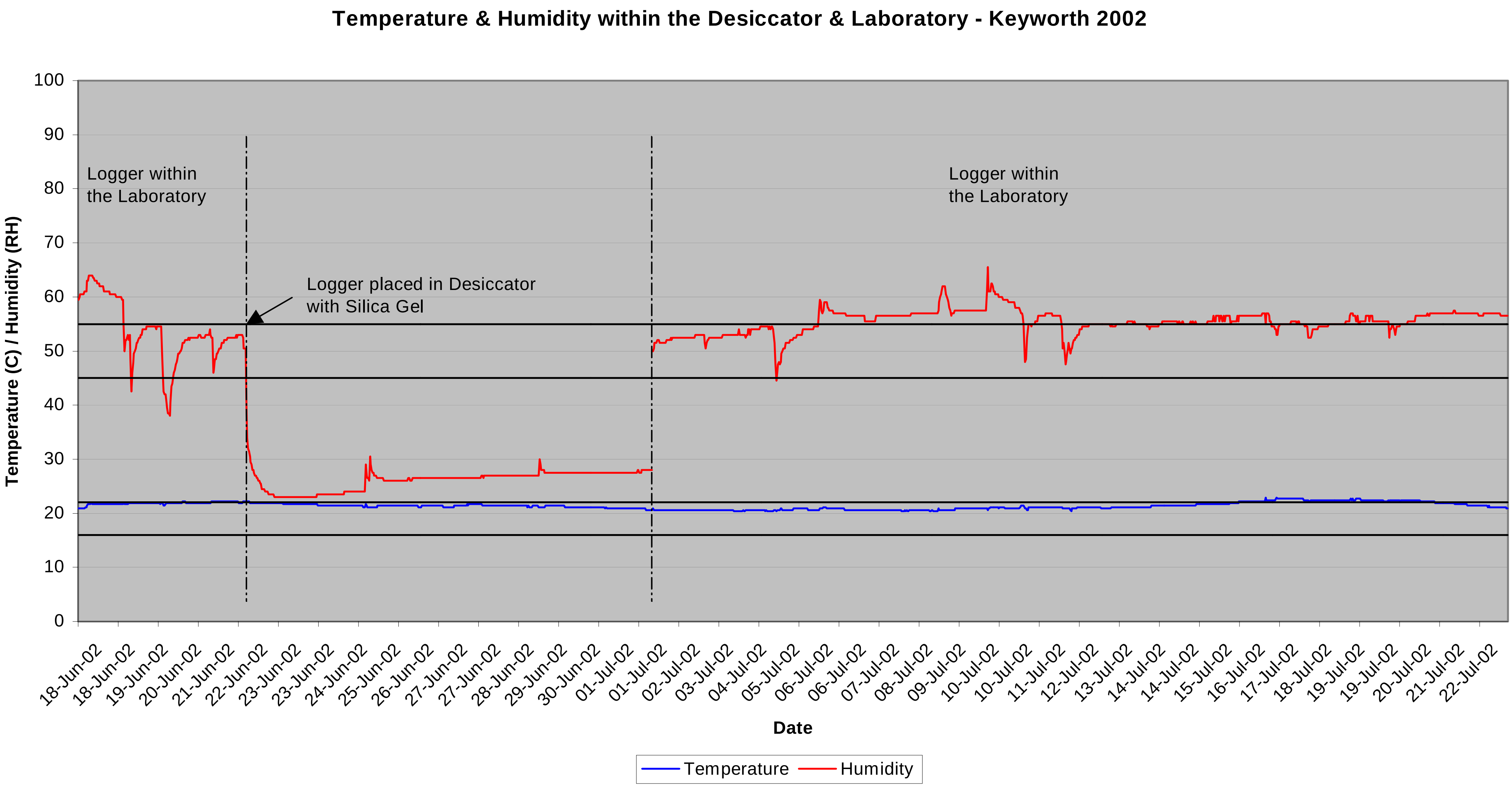


**Figure 14: Temperature and humidity readings within the Desiccator and Laboratory**

### 2.4.5 Strong Room: NGRC

The NGRC (National Geological Records Centre) houses an archival collection of reports, notebook interpretations, plans and other geological or related data received from external organisations that are not part of any other collections. As this centre is recognised as a place of deposit for public records it is imperative that these should be stored in the correct environment. The most important materials are kept in the 'strong room' situated close to the NGRC. This storage area is fireproof and has an automated fire suppression system built in.

The ambient temperature and relative humidity values for storage conditions of historical records on paper should be between 13-18°C and 55-65 %, respectively, as stated in the *Standards in the Museum Care of Geological Collections 1993*. The humidity may be as low as 50% if parchment or vellum is not present, as stated in *Guidelines for the Curation of Geological Materials 1985*. The mobile logger was used for this mini project and commenced on 26th August 2003 until the present day.

#### 2.4.5.1 Strong Room: NGRC Results

The results for the strong room can be seen in Figure 15. There are instances within this graph where data is missing; this is due to the monitor not recording, or being positioned within another location.

Throughout this monitoring period the majority of the readings are stable only showing slight variations. However the temperature readings are slightly higher than the ambient storage conditions of 13-18°C. There are a number of instances where the temperature levels fall dramatically. After having a look at the data there is no pattern for these occurrences and must be due to irregular readings in the monitor. At the end of October the monologger was re-programmed; from the point onwards no additional irregular readings have occurred.

The humidity sensor has produced variable readings; there is only one occasion where the humidity levels are unacceptable. This occurred from Friday 26th September through to Sunday 29th September where a rapid rise to 84% humidity took place. This must be due to inaccuracies in the logger as no temperature readings were received at the same time. Unfortunately, no humidity readings fall within the 55-65 % humidity range there are couple of instances where the values just reach 55%. If this storage area does not include parchment or vellum at any time then a proportion of the humidity readings are within the minimum 50% humidity threshold.

#### 2.4.5.2 Strong Room Summary

From the results it can be seen that the temperature and humidity values are within the recommended ambient conditions for general collections. For the recommended ranges for historic paper documents, the temperature is generally higher than the ideal range, whilst the humidity falls short of the ambient values required for the storage of paper. The climatic condition in which to store such material is often difficult to attain, and so it is best to find a compromise between the requirements and the resources available. *Brunton et al (1985).*

Even though previous monitoring results do exist they are not from the same type of monitor used in this mini project. Further monitoring should continue, so comparisons between this data and future readings obtained can be made. Due to the importance of this storage area a monologger should set-up to record these conditions on a continual basis.

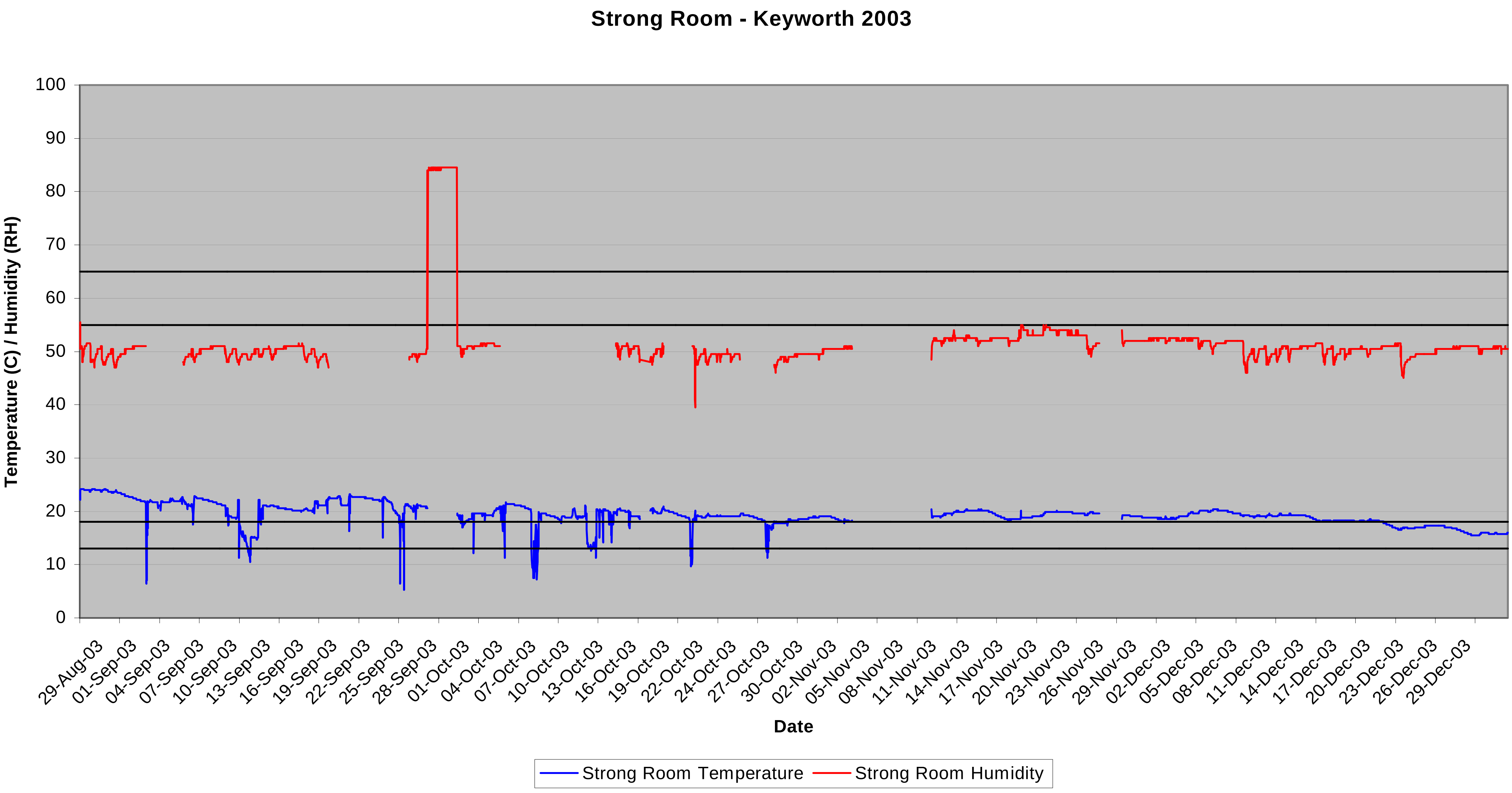


**Figure 15: Temperature and humidity values within the Strong Room**

### 2.4.6 Weather Station

The weather station (Stevenson Screen) provides us with the external climatic readings, which are used for comparative purposes within the storage areas. It has been interesting to see how accurate the readings are and to see daily variations in temperature and humidity. The mobile monologger was placed in the weather station on two separate occasions, from the beginning to the end of August 2003.

#### 2.4.6.1 Weather Station Results

Figure 16 shows readings within the Stevenson Screen. Differences in the graph structure between the Stevenson Screen and the monologger values are due to the frequency the readings were taken. Every twenty-four hours for the thermometers and extracted every thirty minutes from the data recorded by the monologger.

By looking at the graph and the data recorded at 9:00 (GMT) both types of monitors have identical temperature readings and the humidity readings are only a few percent different. The monologger is also showing the variations throughout the day, which are not being recorded from the thermometers.

As the thermometers can also measure the maximum and minimum temperatures within the preceding twenty-four hours two additional lines have been plotted (yellow and green line). This shows accurately that both types of monitor are recording the extremes in temperature. Therefore it is likely that the maximum and minimum humidity values of the monologger are accurate.

#### 2.4.6.2 Weather Station Summary

It can be seen that the thermometers within the weather station are providing similar readings as the monologger, even though a small percentage of time is being monitored by comparison to the monologger. This could provide us with additional readings throughout the day that could be used for internal comparisons.

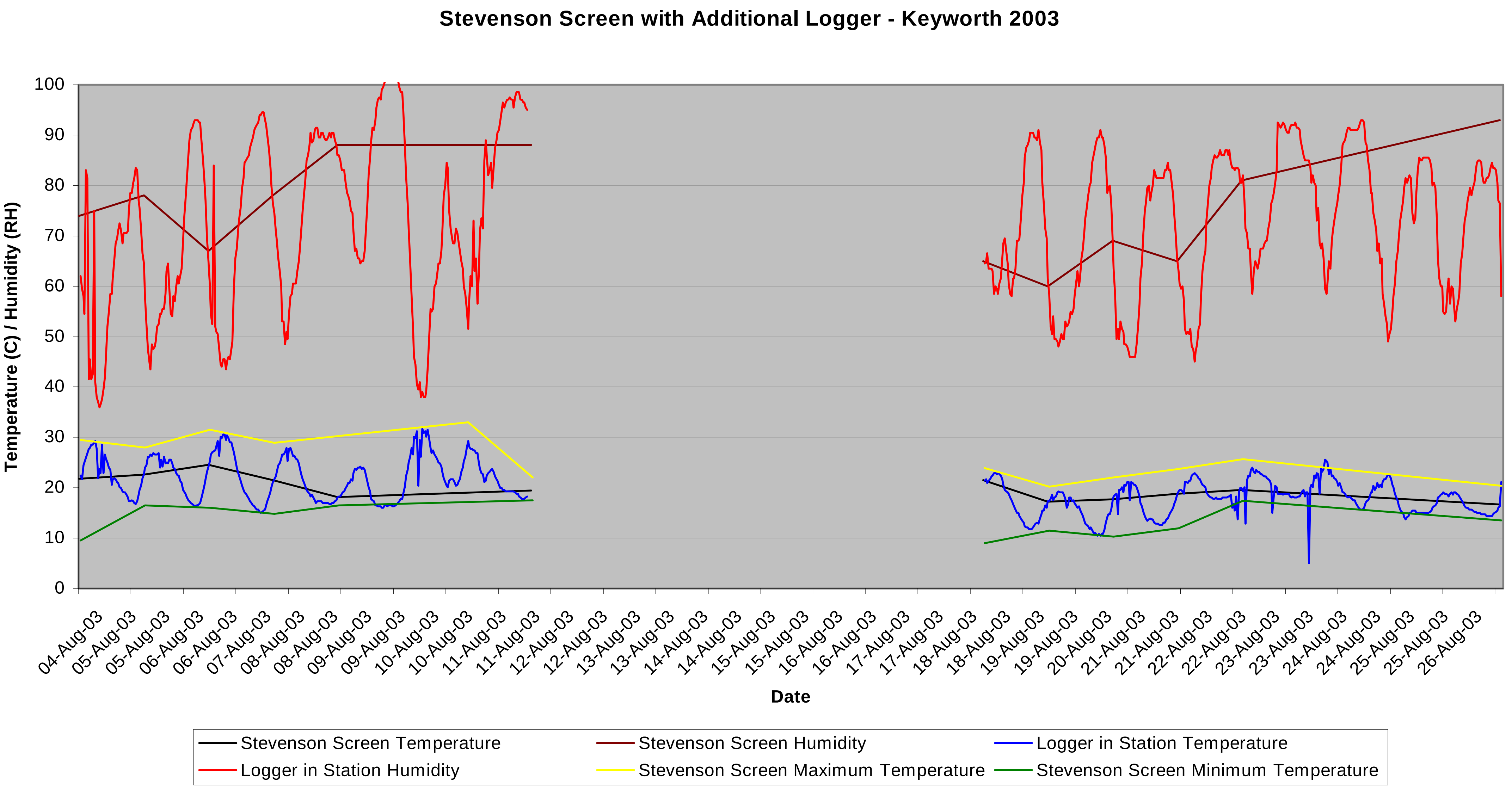


**Figure 16: Temperature and humidity values within the Stevenson Screen**

## 2.5 RECOMMENDATIONS FOR KEYWORTH

### 2.5.1 General monitoring

Monitoring within the main storage areas must continue so we can assess the effects that temperature and humidity are having on the collections; this includes records held in the strong room.

We need to identify areas that could be susceptible to damp, high / low temperatures etc. and then to include additional monitors within these areas. Dehumidifiers could be used to help stabilise any excessive humidity levels. Should this be deemed necessary and become available possibly relocate high risk or irreplaceable items closer to the dehumidifiers. If this is ineffective or too costly, re-locate samples away from these areas where higher humidity levels exist. Such methods could also be applied to areas of unacceptable temperatures.

Where humidity levels fall below the recommended parameters, for example during winter months. Humidifiers may be placed in these areas to improve the humidity levels. Where it is not feasible due to the size of these areas, larger microclimates could created to house sensitive materials.

During the winter months where temperatures fall below the acceptable levels, i.e. the core store extension and the museum, we could increase the minimum thermostat control, or install portable heating equipment.

Visual data could be produced in the form of monthly histograms for all of the main areas. This would chart variations outside of the recommended parameters and quickly identify problems within the storage areas. An example would be within the museum when temperature and humidity rise during the summer. When these values exceed the recommended levels the air extraction system could be turned on. Such histograms would show any seasonal variations occurring and would demonstrate our performance in maintaining a suitable environment for the collections.

The information gathered from this report and any further data gathered from the environmental monitoring of the Collections may be used by the Conservator to provide us with a risk assessment for materials held within certain storage areas.

### 2.5.2 Core store

Shutter doors between the core store extension and the pallet store should be shut when these areas are not occupied. These practices should also be adopted for the shutter door at the rear of the core store leading to the loading bay area. This will help to maintain more stable conditions within these areas.

### 2.5.3 Museum

The museum cabinet doors should be shut and locked at all times whilst not in use, especially during the evenings and weekends. Such practises will help to maintain the buffer effect and protect the specimens from any climatic variations in the museum.

To reduce the effects of solar heating within the museum window blinds should be drawn especially when areas are unoccupied. The use of a light reflective film against the windows would also reduce these effects. A long-term improvement could be the installation of specially manufactured windows, which can reflect the heat away from the window yet enabling light to penetrate.

Any future problems with the heating system in the museum or any other defects within any storage area should be brought to the immediate attention of the appropriate authorities. An assessment for all areas should be drawn up and assessed on a regular basis.

Where the locations of sensitive materials are known, full conditional surveys should be carried out and where necessary conditioned microclimates should be created, monitored and assessed on a regular basis. Assessments could be on a six monthly basis and every two months throughout the summer when humidity levels are often higher. Any additional sensitive material identified, old or new should also be included.

A number of large specimens i.e. Woolly Rhinoceros, Mammoth, extinct Bison and Ox are currently being displayed above the wall cabinets in the museum. If possible these should be re-assigned a new environment where the recommended temperature and humidity levels for sub-fossil bone can be maintained. Storage could either be in a wall cabinet or specially manufactured display cases that could house these specimens in their current location. These microclimates would need to be monitored on a regular basis. If neither options are implemented then a continual assessment of their current location and condition should be made.

In the forthcoming year or so the museum wall cabinets will be re-organised to house a collection of fossil material collected by Mantell, Buckman, Owens, Kidston and Edgell. The use of spot lighting could be installed within these cabinets to enhance the appearance of the collections to the public. Thought must be taken when choosing the type of lighting as the heat from the light could increase the temperature within this microclimate and therefore cause substantial damage to the fossils within. Low voltage lighting is preferred and monitoring of these cabinets should be on a continual basis.

### 2.5.4 Pyrite Decay & Damp Meter

Any material that has been identified as having pyrite decay should be flagged up immediately.

On the discovery of pyrite decay a mobile logger should be placed in the affected tray, which should then be re-sealed and monitored for the duration of one week. After this time the tray may be worked on by the Conservator who would carry out a conditional survey prior to remedial conservation work. Whilst the Conservator is assessing the tray the void left in the tray racking may be monitored with the mobile logger to ascertain if the problem is specimen related or due to the conditions in which the tray is stored. At the same time, the trays in the immediate vicinity should also be checked for similar signs of decay. The level of moisture in the tray where the sample was found, and of those in the surrounding trays, should also be measured. The addition of this data may allow the early identification of pyrite decay in wooden and cardboard storage trays.

Members of staff who use the collections regularly could be trained to recognise the signs of sample deterioration, pyrite decay and efflorescence for example. Prompt identification of specimens giving cause for concern being brought to the attention of the Conservator for assessment will improve the quality of the collection.

### 2.5.5 Additional Monitors

Where the budget allows additional monitors should be purchased. This would enable any problem areas, to be monitored and investigated further.

A damp meter should be purchased to allow monitoring of moisture in the wooden and cardboard trays.

It would be beneficial for the Casella 500+ on the first floor of the museum to either be repaired or replaced, as it is presently only effective at recording temperature readings. Once this is done valuable monitoring of all data can resume.

An additional monitor could be located in the Stevenson Screen to continually monitor the external temperature and humidity. This would provide us with more readings throughout the day and record values over weekends. Such data would help us to compare internal and external readings more accurately.

The eventual replacement of the two thermohygrographs situated within the museum and the core store with monologgers. This would enable easier extraction and manipulation of the data. The thermomhygrographs could still be used as visual aids in assessing the climatic conditions within problem areas whilst the monologgers are recording data.

Calibration of the monitors should be carried out on a regular basis throughout the year if additional monitors are purchased then these could be used as benchmarks in the calibration method as they would be the most accurate devices. If the funds became available then the monitors should be re-calibrated professionally.

### 2.5.6 Future Additional Projects

Examples of future projects could include:

- To re-investigate the storage containers already monitored so we can ascertain if the buffering effects seen remain constant as the humidity levels change throughout the year. For this to happen an additional monitor would be needed for twelve months.
- To monitor the effects of different storage containers, i.e. wood, plastic, cardboard, and make comparisons. This could also include monitoring trays containing different materials, i.e. clays, shale's, chalks and minerals.
- To monitor different sections within the same storage area at the same time. This should show us any differences within that storage facility. From this, information 'hot-spots' could be controlled or specimens relocated to areas where the climates identified best suit their needs.
- Monitor the effects of the air circulation system within the core store and museum to evaluate how the temperature and humidity differs at different heights and distances from the heating source.
- Detailed monitoring of the collections could be conducted to measure the effects of the central heating system being turned off at weekends.
- Monitor the storage rooms used to house registers and paper records for the museum collections; this also could include the museum library.
- Further tests on the Silica Gel could be carried out to assess the effectiveness over time of this medium within a microclimate.

# 3 Monitoring at Murchison House

Six Digitron loggers are used to gather temperature and humidity data in Murchison House, three each in the Palaeontological & Petrological stores, see Figure 1. A seventh system, located on the southeast roof of Murchison House, is used to capture data from outside the building.

In the Palaeontological area there is one in a Museum specimens cabinet and one each in a wooden tray and a plastic tray, both covered, in the general store.

The monitors in the Petrological store are situated in such a way as to show the difference between the environment in a closed plastic tray and the environment in the open store. The third has recently been added to monitor an area of particular concern and is also in the open.

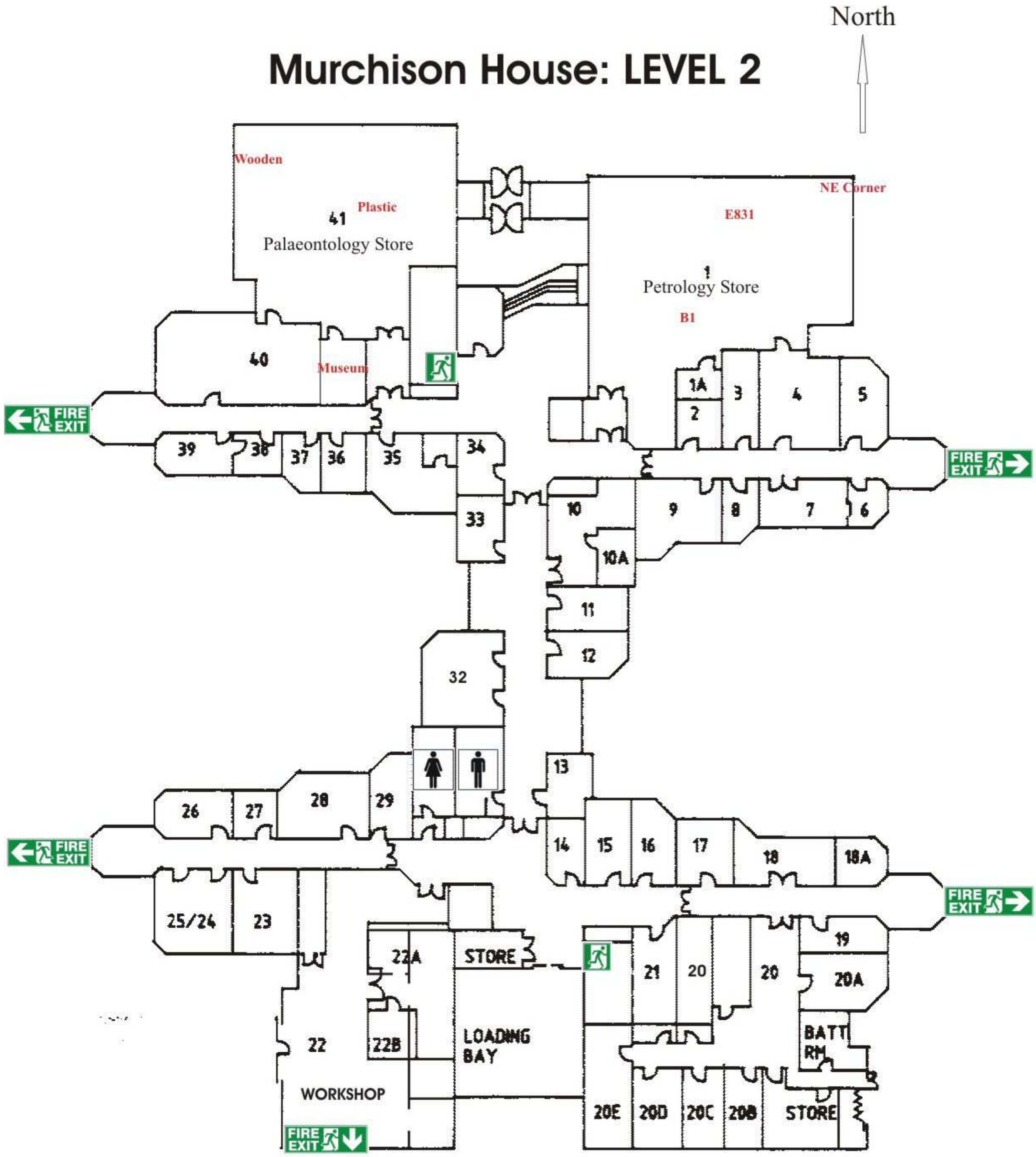


**Figure 17: Location of Murchison House loggers**

Internal data is download every Tuesday (to avoid Monday holidays) at approximately 10am. By downloading on the same day and time every week errors or sampling artefacts can be easily identified.

Loggers are collected from their locations, taken to another room for the data to be downloaded to a personal computer. They are then re-armed before being returned to the same locations. The loggers are labelled to avoid any confusion.

Data are saved to logger compact file format, readable only with the propriety software supplied with the instruments, and have the extension lcf. These are the master files.

To allow data to be imported into other programs, such as Microsoft Excel and MSAccess, the lcf files are converted to comma delimited text file format, and have the extension csv.

Data was originally recorded at hourly intervals. This allowed the loggers to be downloaded every 3 or 4 months. At the time it was felt that this was all that was required. However an event captured on one of the loggers highlighted the requirement to change the regime to allow the environment to be more closely monitored.

From 4 November 2002 the sampling rate was changed to every 3 minutes. The increase in staff time to download, convert and manipulate the data is less important than the need to be aware of what is happening to the environment in the stores.

The data is stored in a Microsoft Access database. This format is the most space efficient and data is easily exported to other formats for graphing purposes. The csv files are combined in one file and imported to MSAccess. The table created is then appended to the rest of the data.

As stated above, the data from the loggers are now primed to recorded in 3 minutes intervals, however for the purpose of graphing for a calendar year only readings every half hour are required. An MSExcel query is used to extract the data from the Access database.

As the computers used to download the data are adjusted automatically to daylight saving or British Summer Time (BST) the data in the Access database are stored in local time. To standardise the Keyworth & Edinburgh data to Greenwich Mean Time, (GMT), conversions are made in the Excel spreadsheets. Alterations are also made to the data to allow for the variance in the readings of the loggers, explained in the following chapter.

Data from the Weather Station are downloaded as ASCII files with the extensions .MHU and .MTA (Murchison House Humidity & Murchison House Temperature).

The files are converted into MSExcel format, calibrated and imported to an MSAccess database. All data are recorded in GMT and require no alteration from BST and are stored in an Access database, in GMT.

To clarify the status of the saved files in the various formats: all .lcf files, individual logger files with the extension .csv and the MSAccess database contain 'raw data'; the data is uncalibrated and in local time. The lcf files are the master files.

Weather Station data in .MHU and .MTA files are raw data in ASCII format, these are the master files for this data. Data stored in the associated MSAccess database is calibrated and in GMT.

The Excel spreadsheets labelled "MH 30 minutes 2002.xls" and "MH 30 minutes 2003.xls" contain data for 2002 and 2003 extracted from the MSAccess database. The data in these files have been calibrated and altered to GMT. It is from these files that the annual graphs and 'mini-project' files are produced.

The Excel spreadsheet labelled "Met data 2003.xls" contains all Weather Station data up to 31st December 2003 in 30-minute intervals. It is from this file that the external data graph is produced.

### 3.1 CALIBRATION

When purchased, the loggers are guaranteed for accuracy of +/-0.3°C with an average resolution of +/-0.3°C.

When the data was graphed it was noted that the loggers in different locations did not have the same values. Initially this was put down to the locations and material the trays were made from.

On further inspection over a period of months, the graphs showed an almost parallel variance. It was thought this could be due to a slight offset in each of the loggers, rather than location or the trays.

An approach was made to the supplier to have older instruments recalibrated to ensure their accuracy was still as high as it was when purchased and to give calibration factors against which to measure one logger against the other. However, it was found that the cost of certification and recalibration was only slightly less than a new instrument.

Methods of calibration were discussed and it was discovered that there was a two-tier certification system and therefore cost regime. The 'premier' method was to calibrate each instrument as would be done the first time it was assembled. The loggers would be certificated guaranteeing their accuracy.

The other method, less expensive than the first, is for one only logger to be calibrated and certificated. This is then put in a sealed container with the other loggers for 24 hours after which the loggers would be removed and calibrated to the certificated instrument.

As we had only recently purchased new instruments we decided to carry out a calibration test using a similar method to the second system described above using a newly purchased logger as the benchmark.

### 3.1.1 Calibration Method

The loggers were placed in an empty, sealed specimen tray for 28 hours at the end of a 7 day recording period between 12 noon, 30 April and 4pm, 1 May 2003 after which the data was downloaded and graphed. The loggers were then returned to their ‘normal’ locations.

The time was chosen to lessen the loss of data recorded in the stores; it was also similar to the time used by the manufacturers.

The newly purchased logger was included in the calibration exercise as the ‘benchmark’.

It is recognised that this may not be the most accurate method of calibration, however, new loggers are guaranteed to be very accurate, as described above, and the technique chosen similar to one of the manufacturers own methods.

### 3.1.2 Calibration Discussion

An excel macro was utilised to calibrate the loggers. Estimates were made to add or subtract values from the data recovered until the lines converged on the new logger line. The temperature values did not require any alteration but all the humidity values were adjusted by varying amounts.

As can be seen in Table 1 below, the calibration figures are, generally, very small but the associated graph shows that even these small changes make the data more accurate.

| Logger | Temperature | Humidity |
|---|---|---|
| **Museum** | Same | +5.0 |
| **Wooden** | Same | +3.5 |
| **Plastic** | Same | Same |
| **E831** | Same | +0.5 |
| **B1** | Same | +4.5 |

**Table 3: Calibration Values, Edinburgh Digitron Loggers**

The method of calibration is fraught with potential inaccuracies. The duration of the calibration period may not have been long enough, or rigorous enough; the logger selected as the 'benchmark' may not have been the most accurate instrument and the selected calibration values may not have been precise enough.

However, the results obtained from the test period were sufficient to appease any concerns that there were large-scale problems with the rationale or assumptions behind the test.

The cost of manufacturer calibration is such that it cannot be justified compared to the cost of purchasing new equipment in the present financial climate. However, there is a need to continue to recalibrate the loggers against each other to maintain the preserved accuracy of the graphs. There is also a need to extend the number of logging instruments used.

I suggest that in future, as funds become available, a new instrument is purchased and used as the 'benchmark' for a new calibration test in a similar way as described above.

From the Figure 18 below it can be seen that when the loggers were placed in the same location the suspicions that there was an offset between the loggers was proved correct.

The offset is not large, however the results are made more accurate by applying the calibration factor. The benchmark used was the monitor for the Plastic tray (the green line) as it was one most recently purchased, Plate 15 below.

**Plate 15: Plastic Tray**

The graph was examined and offset values estimated for each line compared to the green line for both temperature and humidity. The estimated figure was then added or subtracted from the measured value using an excel macro and the graph redrawn. The final calibration values presented in Table 1 were derived at after fine adjustment of the graphs to achieve a 'best fit' for the calibration period.

To allow the two sets of data to be more easily compared Figure 18, the uncalibrated data is provided as a transparency; note the gaps between the lines at the time when they were in the same location. Figure 19 is the same data, which has had the calibration factors applied.

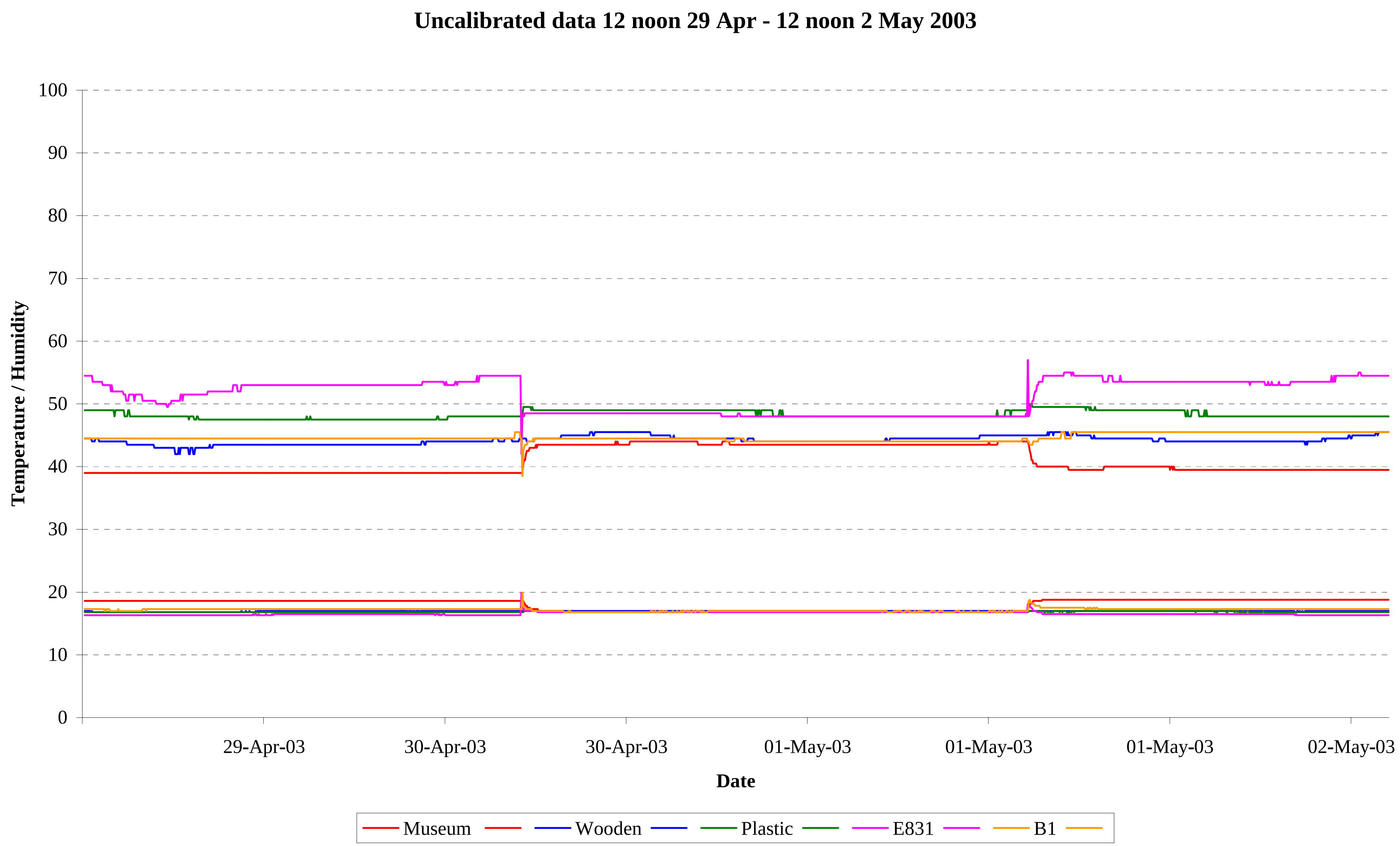


**Figure 18: Uncalibrated data – test period, Murchison House**

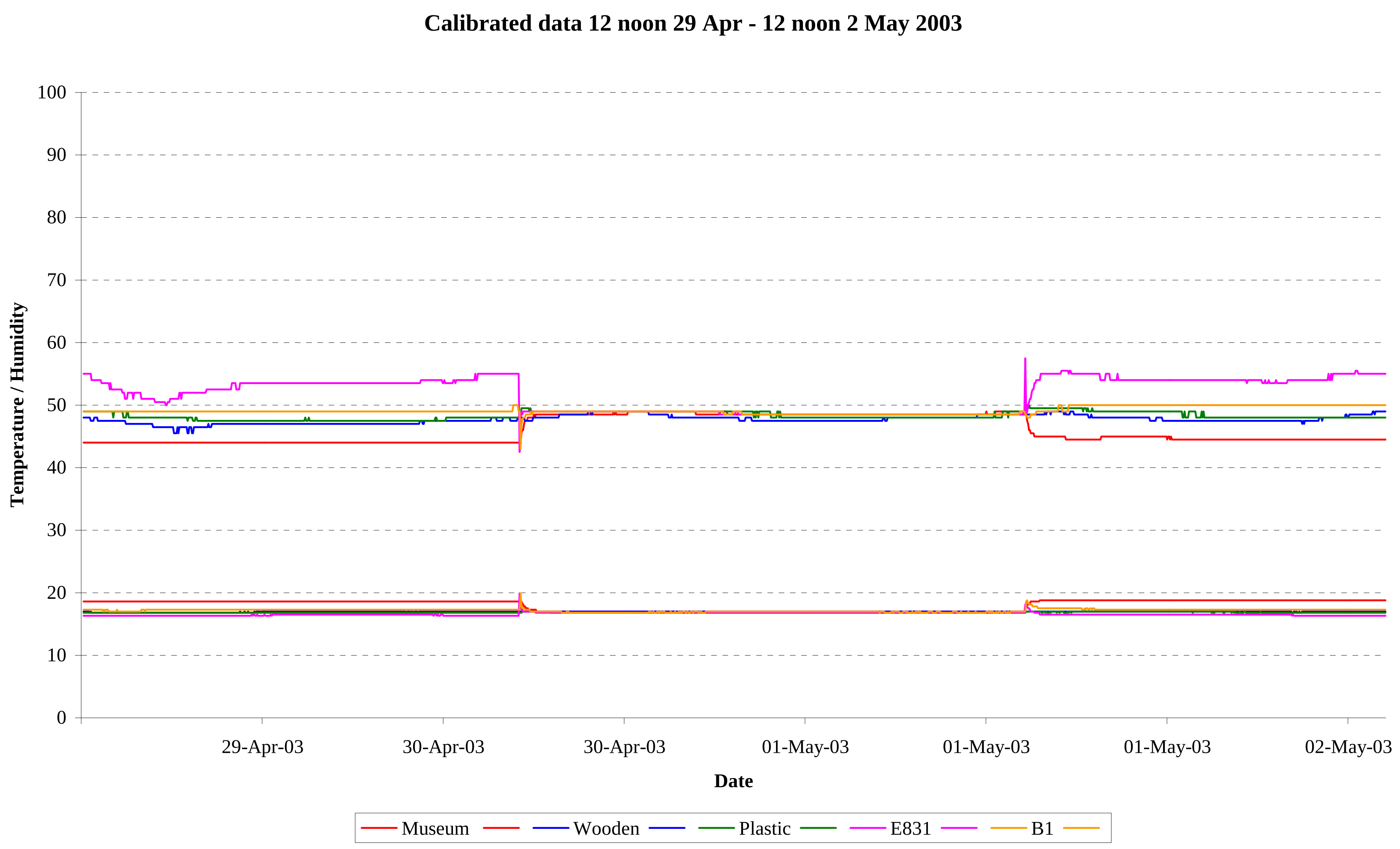


**Figure 19: Calibrated data – test period, Murchison House**

## 3.2 ANNUAL DATA 2003

Six Digitron loggers are used to gather temperature and humidity data in Murchison House, three each in the Palaeontological & Petrology stores, see Figure 17 above.

**Plate 16: Museum Tray**

Two loggers in the Palaeontological area are in trays in the general store, Plates 15 & 17, and the other in a Museum specimen's cabinet, Plate 16. These loggers have been in place from the beginning of the monitoring programme in December 2000/March 2001.

**Plate 17: Wooden Tray**

Monitoring in the Petrology store commenced in April 2002. One monitor in the store is housed in a closed plastic tray and another in an open tray. A third, which has only been in place from July 2003, is situated on the floor in a corner of the store in response to comments by staff.

As discussed in previous chapters the data presented in this chapter has been calibrated to take variations in the accuracy of individual loggers into account. The time has also been altered to Greenwich Mean Time (GMT).

This chapter will confine discussion to general trends and comparisons with 2002; particular events will be discussed in later chapters.

**Plate 18: Tray B1**

### 3.2.1 Annual Data Discussion

The data presented in Figure 20 shows an improvement in the general conditions in both storerooms in the calendar year 2003 compared to the previous 12 months; see Figure 21.

There is no doubt that the warm, dry summer will have played a part in this, however it is presumed that improvements to the rooms and working practices will also have had an effect.

The humidity remained within the desired 45-55% RH bracket for longer in 2003 than in 2002. For most of the locations in 2003 only eight to ten weeks was outwith the bracket compared to almost 6 months in 2002!

The temperatures in 2003 are lower than suggested in Standards in the Museum Care of Geological Collections, 1993, but once again there is an improvement on 2002.

As may be expected the recorded temperatures are best during late spring to late summer. The high humidity recorded in mid summer 2002 did not manifest itself in 2003, which hopefully means it was a one-off event.

From the graphs it can be seen that the larger, more exposed, petrology store has a slightly inferior environment than the smaller palaeontology store.

The general trend for all the loggers is similar, which could be said to be remarkable given that they are not all in the same store. However, they do face the same direction, north, and both have large external walls.

**Plate 19: NE Corner**

The storerooms do not have heating facilities and so it is not a simple, or cheap, option increase the temperatures during cooler periods.

The encouraging aspect of the temperature graphs is that there are no sudden, dramatic rises or dips recorded.  Any changes occur over a period of days and are generally small increases.  The obvious contradiction of this the NE Corner, which appears to be more affected by alterations in the temperature than the other locations.

Tray B1, Plate 18, is similar to the Plastic tray in the Palaeontology store.  The NE Corner, Plate 19 and E831, Plate 20, are the only two loggers that are not covered; this could go some way to explain why these two measurements are consistently the highest.  They are also close to each other, which could explain why the peaks for these two loggers show the highest increase.

**Plate 20: Tray E831**

Examining the weather graph with the 2003 graph, it can be seen that the NE Corner matches the external temperature very well.  There is almost no 'cushioning' provided by the building recorded on this logger.  Many of the peaks and troughs of the weather (Figure 24) are detailed in the NE Corner graph, which are either not present or much less on the other graphs. The humidity also shows no sign of buffering; in fact the area appears to become 'saturated'.

Remedial action has been taken to counter the problems in this corner and it is hoped that the environment here will take a turn for the better.  It is expected that it will take some time to improve due to the level of damage that has been done to the brickwork.

Improvements made to the fabric of the building have made a difference to the stores over the past 12 months and will continue to be reflected in the data recorded on the loggers.

Comparing Figures 22 and 23, one can see just how much of an improvement has been made during 2003. In all cases the percentage of humidity readings within the suggested guidelines has increased, most dramatically in the wooden and plastic trays. These areas also highlight the difficulty of attempting to improve the temperature whilst not detrimentally affecting the humidity.

The graphs show that the marked improvement in temperature has increased the number of readings within the guidelines, however an increased number when compared to 2002 were below the lower level.

The improvements in the Palaeontology store were due in the main to the damp problem in June 2002 not repeating in 2003. It is hoped the action taken after this incident will negate this risk in the future.

The challenge for 2004 is to build on the improvement made in 2003. It may prove difficult for certain areas, the museum for example, however both general stores do have room for improvement and it is these that will be targeted.

Discussions are taking place with Facilities Management on possible ways of creating better environments and an additional challenge is to carry out the works required within a tight budget.

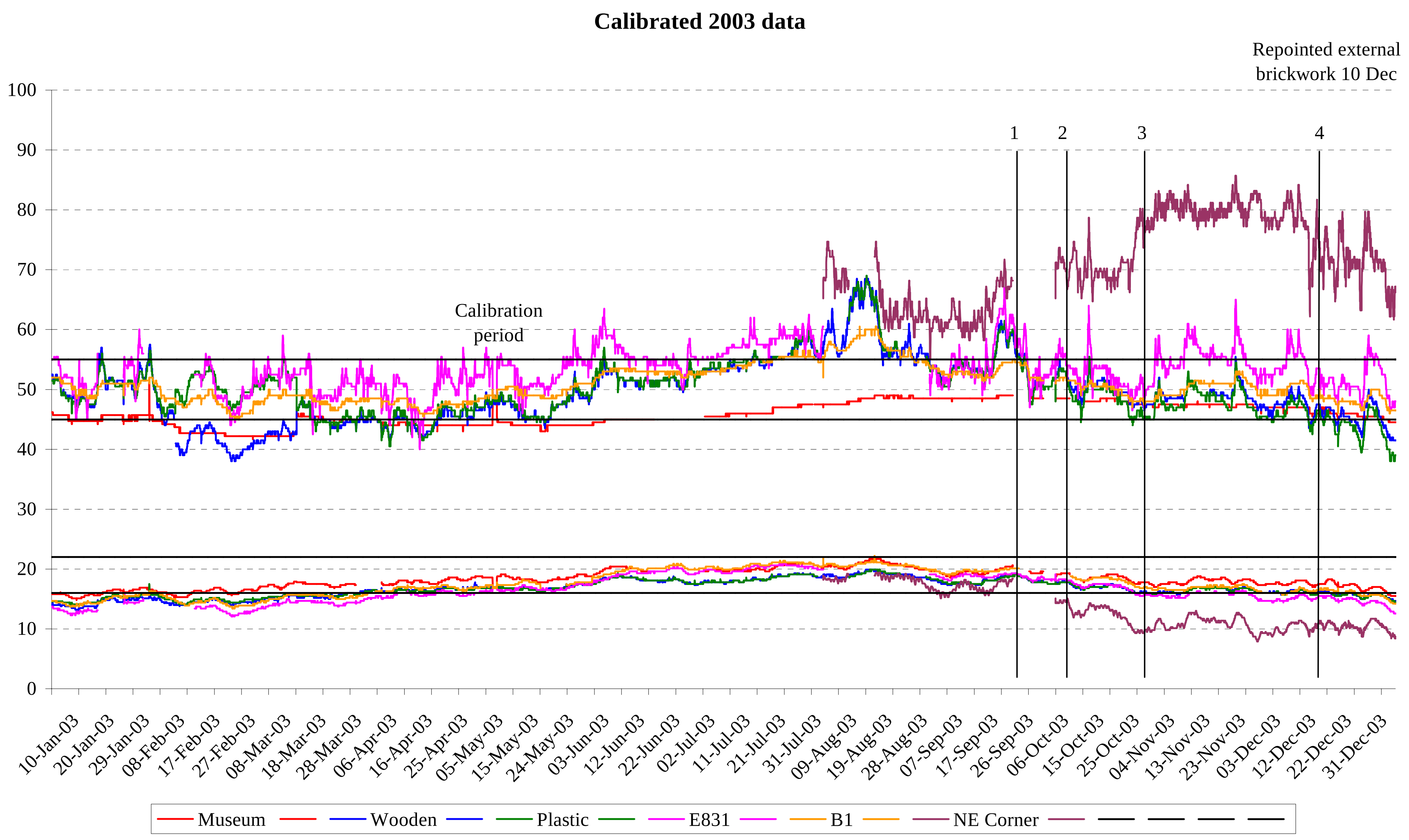


**Figure 20: Calibrated data 2003, Murchison House**

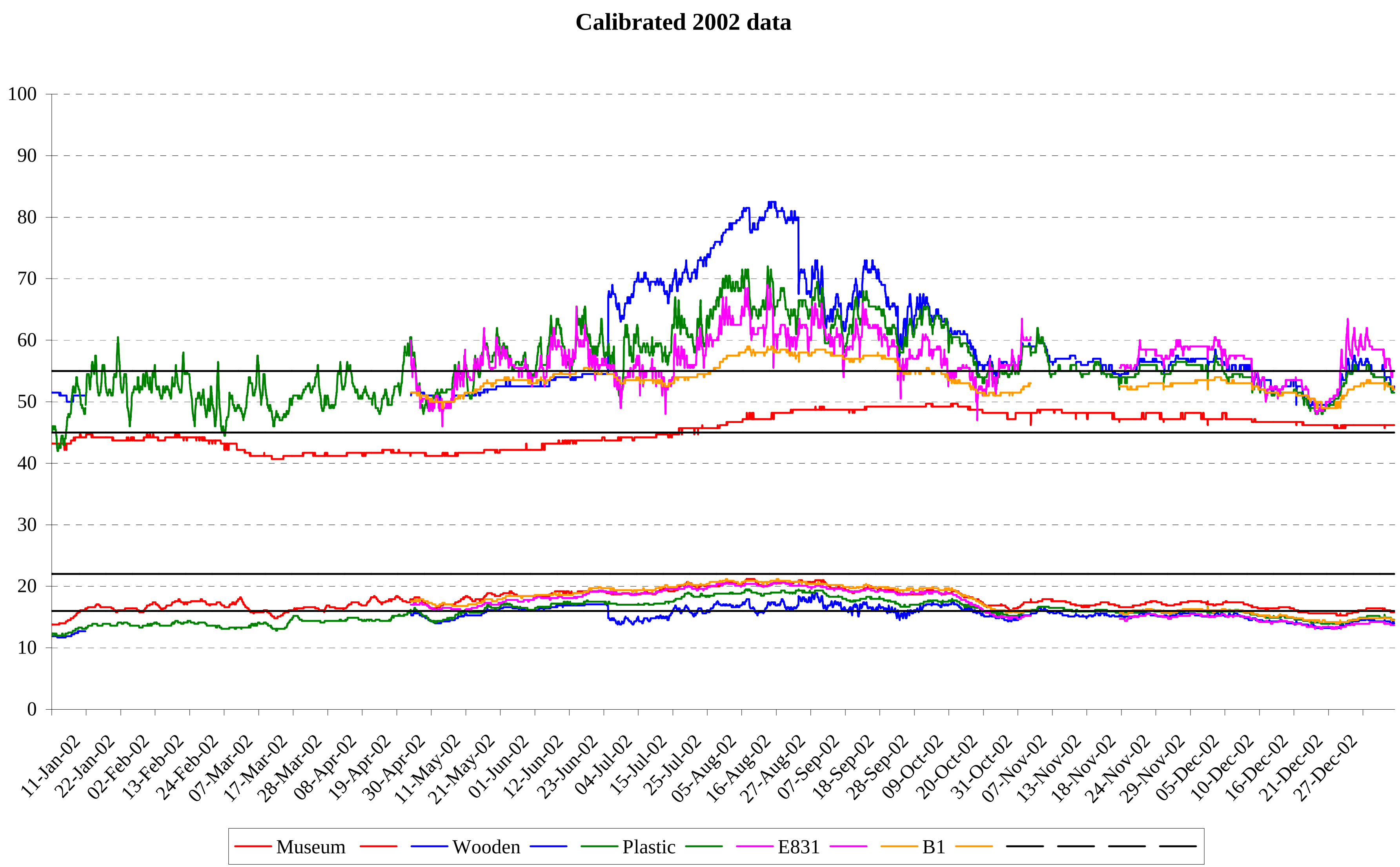


**Figure 21: Calibrated data 2002, Murchison House**

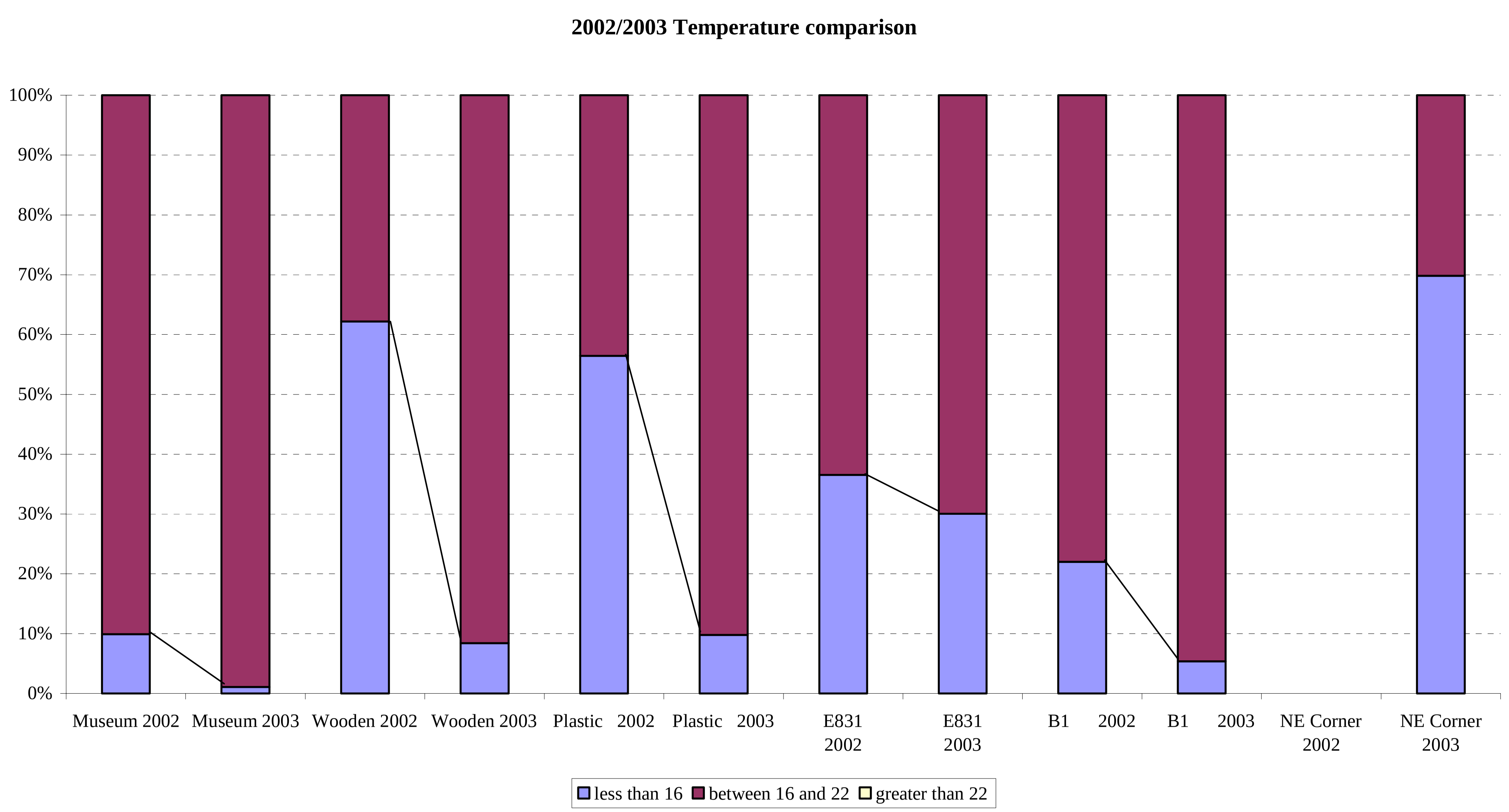


**Figure 22: 2002/2003 Temperature comparisons, Murchison House**

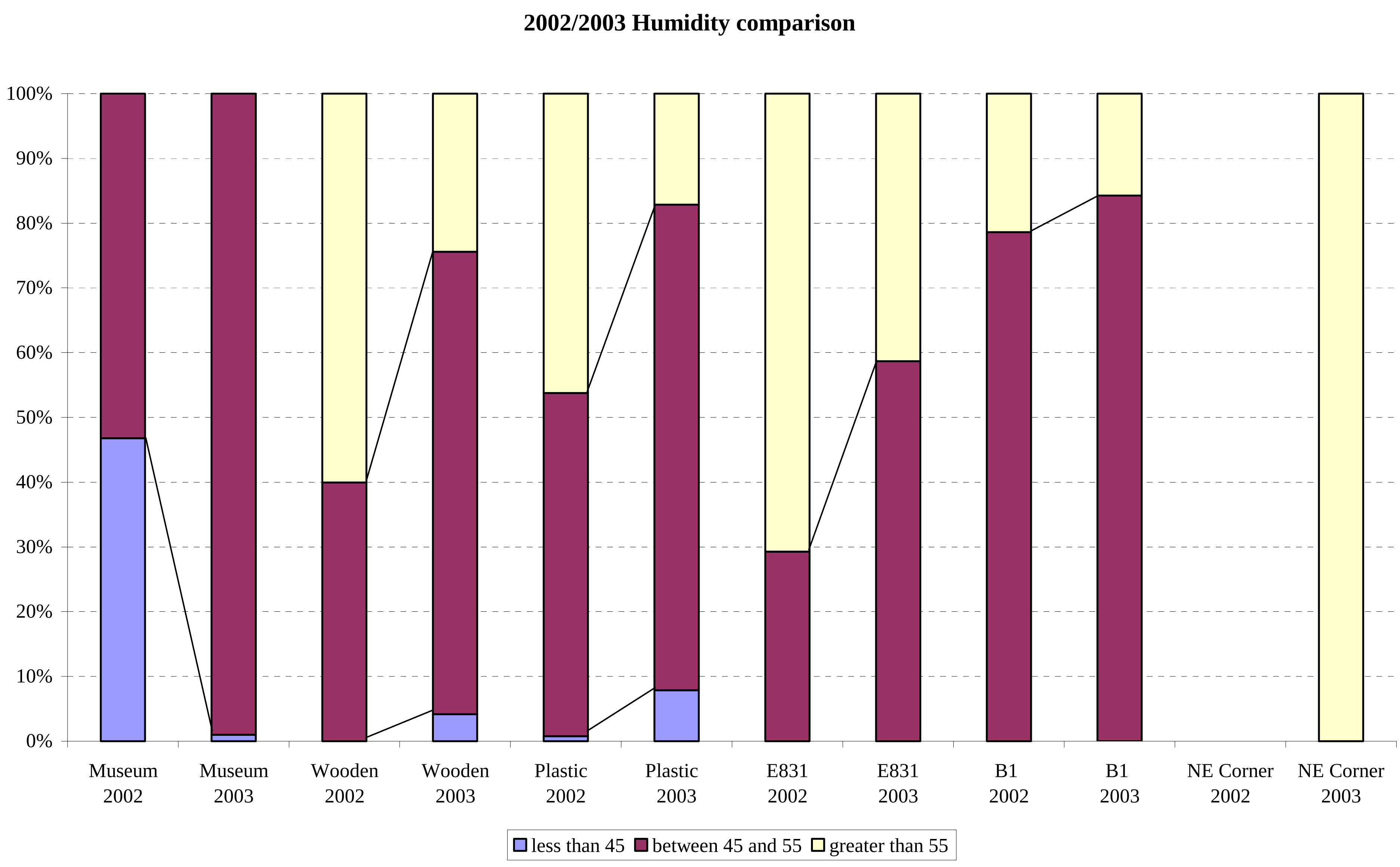


**Figure 23: 2002/2003 Humidity comparisons, Murchison House**

## 3.3 ANNUAL WEATHER DATA 2003

Analytical data for the weather at Murchison House has only been routinely available since July 2003. The data are recorded from a BGS built weather station situated on the roof of Murchison House; see Plate 5.

Before this from September 2002, a twice-daily record was made of sunshine, cloud cover, precipitation and subjective temperature ('very hot' to 'freezing'). Although not absolute, it did provide a rough check against whether a rise in storeroom humidity could be due to internal or external influences.

### 3.3.1 Annual Weather Discussion

The fluctuation in the external temperature and humidity, even at 30-minute intervals, provides a graph with too much information to be readable. To make the graph legible a trend line has been added for both the temperature and humidity.

As discussed in a previous chapter, the weather station has not been calibrated against the other loggers and its accuracy is unknown. This obviously reduces the confidence we have in the data and therefore the trend lines are the best method to view the associated curves. They also provide clear lines to compare with those of the tray data.

The weather graph has been provided as a transparency to allow it to be placed over the annual data, Figure 20, for comparative purposes.

Referring to Figures 20, Calibrated 2003 data and 24, External Temperature and Humidity – Murchison House, I would like to highlight a few, important, points that provided us with the information that there was an issue with the integrity of the storeroom.

Changes in the air temperature and humidity levels outside will be reflected in any instruments housed indoors. However, a wind and watertight building is expected to offer some buffering against these fluctuations. The orientation of the building, the material from which it is built and the internal heating will create a climate less harsh than that outside. However, if there is a defect in the building allowing either the wind or rain, or both, in then it is expected a change of the ambient conditions will be recorded.

Comparing the weather and internal data for the same period shows the clear association with the external temperature and that of the stores, particularly the NE Corner. There is also an apparent relationship between the humidity recorded at these two locations, although not as distinct the temperature.

What is unusual is that whilst 5 loggers appear to be well buffered, the logger in the NE Corner of the Petrography store does not. This, we concluded, was due to a localised problem; although one that would have negative effects on the rest of the store.

From the commencement of recording data in the NE Corner to point 1 on Figure 20 there is a close relationship with the external temperature and humidity and the NE Corner; they almost overlap.

The temperatures for both loggers follow a similar trend to the end of the year. There is only a very slight 'damping' of the internal, NE Corner, readings when compared to the outside. This is not reflected in the other readings which are substantially higher.

The humidity readings for the 5 loggers inside, excluding the NE Corner, begin to drop following the trend of the external temperature and subsequent rise in humidity at point 2. At the NE Corner, on the other hand, the humidity remains constant. This deviation is more evident at point 3 where the humidity in the NE Corner has remained constant although the other loggers have decreased by 8%.

Also noticeable is that the humidity at the NE Corner at point 2 is now greater than that outside. At point 3 there is a sharp increase in both readings, however the internal reading does not drop in line with the external measurement.

The failure of the humidity to drop now translates to a differential of over 20% when compared to the other internal loggers and 10% to the outside humidity level!

This unusual and unexpected movement was thought to be caused by water ingression, possibly due to a spill in the office above the store. On investigation, the cause was found to be defective external brickwork, which was repaired at point 4.

The drop in the NE Corner humidity to near that of the outside level after point 4 coincides with the repairs being carried out. It is hoped that the repairs will allow the brickwork to dry out and cause less problems in the store in future.

1Without reference to the external data the cause may not have been noticed as quickly as it was.

Although the weather station has been set up as a test by another project it is hoped that it will remain 'live'. If it does not then another system will have to be established, as it has proven invaluable in determining sources of reading variations.

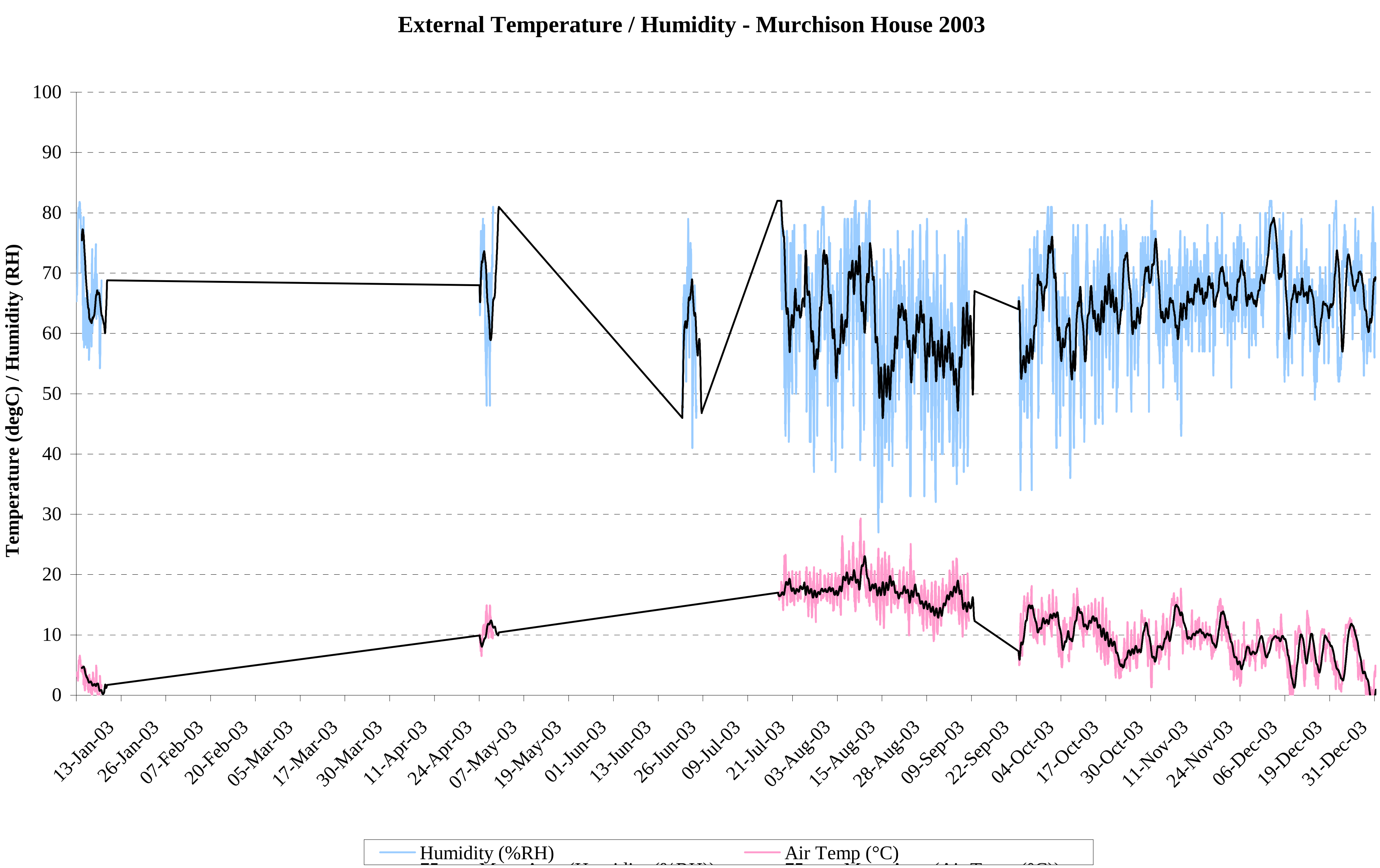


**Figure 24: Weather 2003, Murchison House**

### 3.4 MINI PROJECTS

As this is the first of what will be an annual report I would like to take this opportunity to highlight and discuss certain ‘events’ that have been outwith ‘the norm’ since commencing the programme of data recording in December 2000. In future reports these discussions shall be confined to events over the reporting period.

I would like to discuss three ‘events’ that highlight the need to continuously monitor, at short intervals, the environment within collection storerooms and to examine the fabric of the building.

Each event is significant in itself and each had a major part to play in formulating the method of monitoring as we perform it today.

I shall discuss the events in chronological order, detailing the rationale behind what steps were taken and why. I shall also discuss how the results have affected the way data are examined after the event and what lessons were learnt.

After examination of data showing no clear difference between the 3 loggers installed in the Palaeontology store one of the monitors was moved to a drawer in a museum specimen cabinet on 23 April 2001 to provide environmental data from this valuable collection. As there were still two loggers in the general store the coverage in that area was thought to be sufficient.

In June 2002 a sharp rise in the humidity and a small decrease in the temperature was recorded. Investigations were made into what could have caused this to happen resulting in a series of room improvements and changes in working practices.

A member of the curatorial staff reported a corner he suspected of being damp in the Petrographic storeroom. A logger was put in place and data recorded and examined over the following months. The data showed was that this was an exceptionally damp area, which resulted in a large-scale survey of the external fabric of large sections of Murchison House.

#### 3.4.1 Event 1: Monitor Placement

After discussion with curatorial staff in December 2000, monitors were positioned to record the environment within the Palaeontological storeroom.

Staff had expressed concern that air from outside was entering the store via a disused vent. The perception was that the air was cold and damp and could have a detrimental effect on the condition of the collection, possibly resulting in pyrite decay.

Three Digitron Loggers were borrowed from Facilities Management to provide data on the environment (temperature & humidity) which, it was hoped, would build a case for improvements within the store.

This initial survey was for only two weeks up to the Christmas holidays and we were unable to continue the monitoring until the end of March as the monitors were required elsewhere. However since March 30$^{th}$ 2001 monitoring has continued without break to the present.

The monitors were placed at increasing distances from the vent to provide a broad picture of the store environment. If there was damp air penetrating the vent it should be recorded on the logger closest to it. Loggers farther away should not register any damp air, or have a time lag showing the changes.

#### 3.4.1.1 Event 1: Discussion

Figure 25 below represents the calibrated data for April 2001. The left side of the graph shows the similarity of the data recovered from the three loggers.

Staff concerns that damp air was penetrating the vent were shown to be unfounded, however the vent was sealed from the outside as a result of the concerns raised.

The graph also shows the sudden changes in temperature and humidity recorded when one logger was relocated to a museum cabinet.

Of the three main peaks at the $2^{nd}$, $14^{th}$ and $17^{th}$ April only the first shows a rise in temperature. The lack of a corresponding rise in temperature at the other peaks is interesting and could indicate the influencing factor is internal rather than an external, natural cause.

Unfortunately, at this time neither work patterns nor weather were recorded and therefore we cannot say with any conviction that either was the cause of the rise in humidity. That it affects all three monitors to the same degree indicates it was not localised to one area of the store. One assumption was that a door was jammed open allowing a change of air in the store, however a corresponding change in temperature would also have been expected.

Another possibility is that a number of people were working in the store and that their breathing increased the humidity. This has also been discounted as the possibility of all three monitors being affected at the same time, given their wide spacing, by body influences is remote.

According to the guidelines suggested by the Museums and Galleries Commission (Doughty et al, 1993) the air temperature should be between 16 and 22°C and have a relative humidity of between 45 and 55%.

The environment within the cabinets has proved to be very stable. Although the humidity is low it does not experience the fluctuations of the general store and the temperature is, generally, within the guidelines.

Although the data showed that the environment in the store was not perfect the temperature was relatively stable but the humidity fluctuated between 38 and 57%. The stability of the temperature, although low, is encouraging. The humidity does give cause for concern, however the period when it peaks is reasonably short and it does return to around the same level as it was.

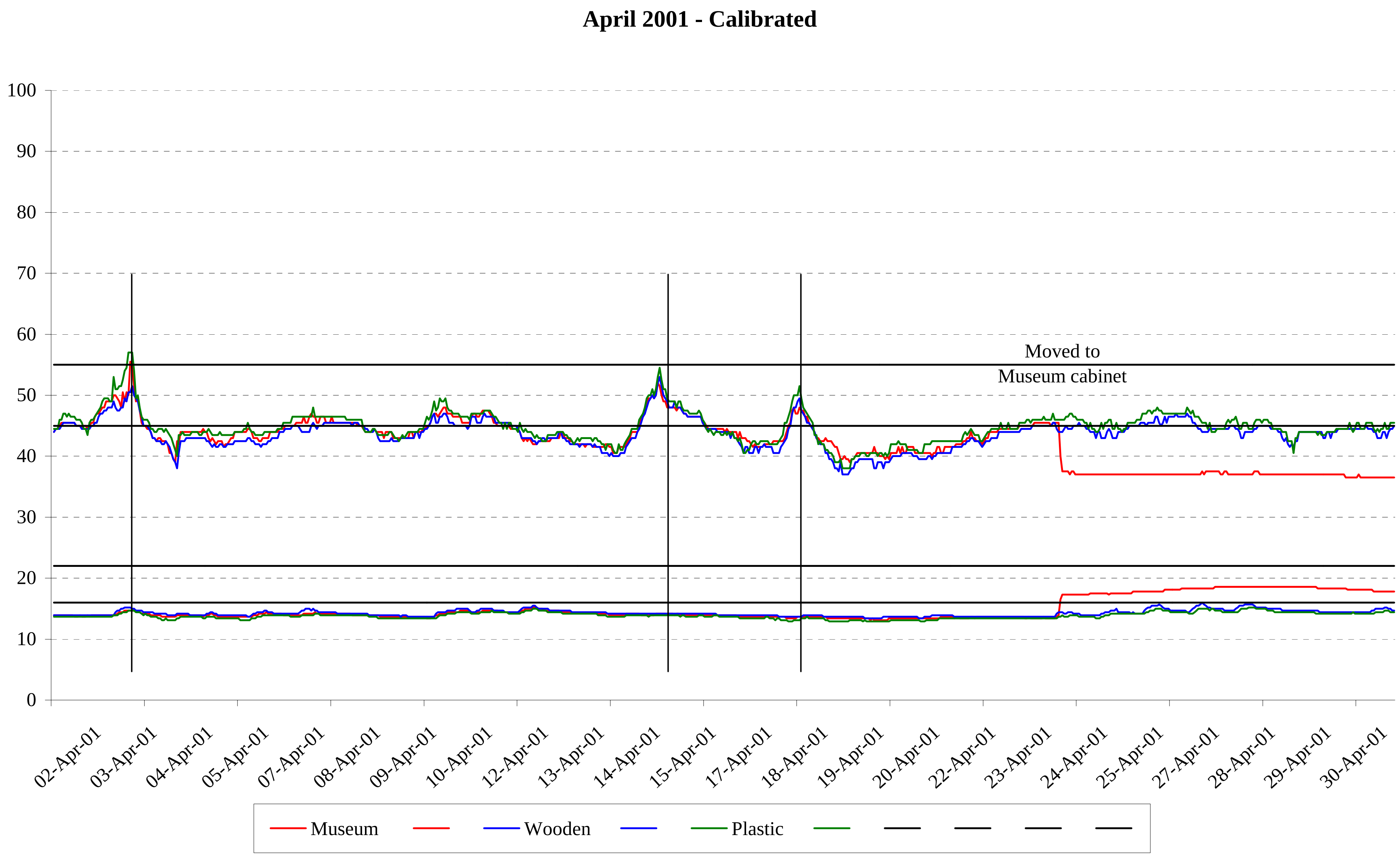


**Figure 25: Palaeontology store April 2001, Murchison House**

### 3.4.2 Event 2: June 2002 'Hiatus'

Figure 26 below represents the calibrated data for five loggers from 8th June 2002 to 7th November 2002. Three are located in the Palaeontology store, Museum, Wooden & Plastic, and two in the Petrology store, E831 & B1. Tray E831 has no lid and is therefore effectively open to the environment in the store, which is reflected in the sharp changes in the readings compared to B1 located in the same store.

Seven points have been highlighted that require some examination and discussion. Some can be explained relatively easily, others are not so obvious.

The main point to note is the very high increase in the humidity at 24th June for the 'wooden' logger (point 1), followed by a similar hike, albeit from a lower point, some days later for the 'plastic' logger. The continued increase (points 2 & 4) and the various decreases (points 3, 5 & 6) are also interesting and worth discussing.

The positive outcome of this event is that improvements have been made to the fabric of the building and working practices have changed.

#### 3.4.2.1 Event 2: Discussion

To aid identification of the discussion points vertical lines have been drawn on the on the graph. To allow the data to be read, the lines have been drawn to the right of the discussed episode.

No apparent reason could be determined for dramatic increase in humidity for the 'Wooden' monitor on June 24th, point 1. An attempt was made to find temperature and rainfall measurements from other sources such as the University of Edinburgh and The Royal Observatory, Edinburgh. Unfortunately although it was normal for these establishments to gather data there was none for this day.

Although no weather data was gathered in Edinburgh at this time it is known that it did not rain on that day nor was the weather any more different to the day before, or after.

All that could be accurately stated was that it was fair with only a slight dew early in the morning and that it did not rain until two or three days later, which is reflected in the rise of the green line. However, unlike the peaks discussed in the previous chapter, the temperature can be seen to dip as would be expected.

The humidity started to fall but increased around the same time as the plastic tray and continued, generally, until 8th August (point 3). Note the increase in humidity for both the plastic and E831 loggers at point 2, 15th July. As these loggers are in different stores this indicates the changes are externally driven. This change can also be seen to a lesser extent in the other loggers which are in other parts of the store, or, in the case of the museum logger, inside a cabinet in an annex of the Palaeontology store.

The 4% dip at point 3 in the wooden tray between 10pm and 6am is reflected in a deeper and longer dip in the plastic tray. The downward movement in the humidity of the plastic tray is twice (8%) that of the wooden and starts at 2pm and continues until 10am the following day, the temperature only decreases by 0.2°. In the Petrology store the open tray, E831, moves between 10am on the 7th and 3pm on the 8th, here the change is 7%. There is a similar pattern at point 4, where both the plastic & open trays have larger movements than the wooden tray.

Although the reason for the changes is unexplained we can see from these figures the wooden tray buffers the change in humidity when compared to a plastic tray or an open shelf.

Point 5 is interesting in that it again illustrates how well the wooden trays buffer the external environment conditions. It also illustrates how important it is not to concentrate solely on the store environment and ignore the conditions within the trays, whatever they are made of.

As has been said previously, the general trend in the wooden tray humidity from 24th June is increasing. However, suddenly on 23rd August, point 5, there is a dramatic decrease and it never reaches the same high again. This is reflected in the plastic and E831 trays, not as a drop but as a levelling out.

This event, which occurred at approximately the same time for all the loggers, was caused by the tray being opened to remove the logger and download the data.

The superior buffering of the wooden tray meant that the damp air in the tray could not escape as readily as that in the plastic or open tray. Between points 3 and 5 the humidity of the plastic and open trays decreased, both by approximately 5%: the humidity of the wooden tray also decreased but by a smaller margin, 1.5%.

The change of air had little effect on the plastic and E831 trays although it could even be argued that there is a slight increase. The important detail is that the wooden tray remains low and mirrors the other trays more closely than previously.

This subject is discussed in more detail in chapter 3.4.4.1 following.

An investigation was instigated to determine the possible cause of the increase. Mortar gaps in the brickwork were discovered near the location of the logger. This was brought to the attention of Facilities Management who checked the rest of the store and filled all defects.

The logging interval was changed from an hourly period to 3 minutes. The loggers are now interrogated weekly, rather than every 3 or 4 months. This was done to allow effective action to be taken if a problem is discovered, which could not be done if data is only examined three times per year.

The loggers were downloaded again at points 6 and 7. You can see that after point 6 the humidity returns to what may be described as ‘normal’.

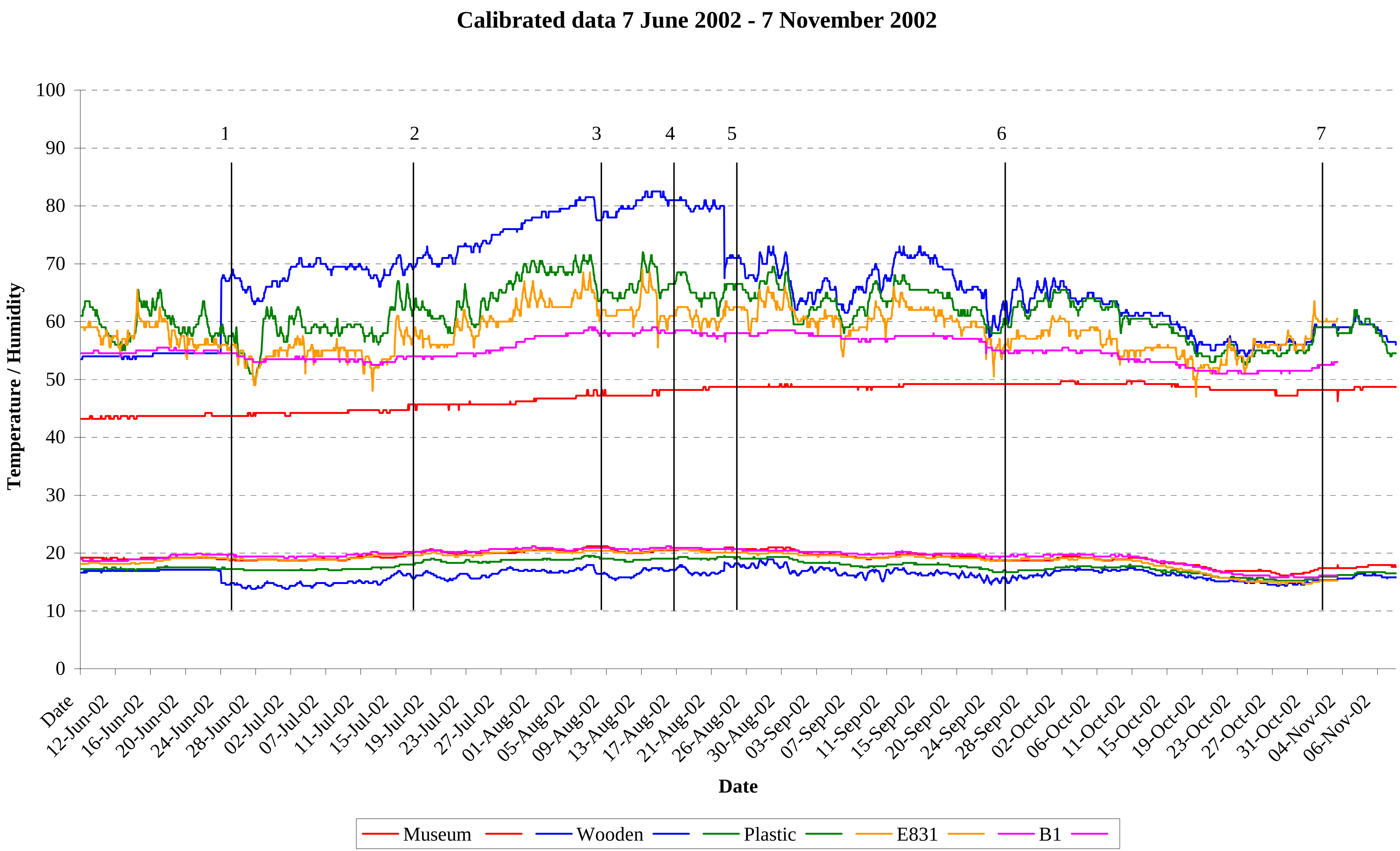


**Figure 26: June 2002 ‘Hiatus’, Murchison House**

### 3.4.3 Event 3: N.E. Corner Petrology Store

A logger was placed in a particular corner of the Petrology store, the northeast corner; after a member of staff reported that it felt damp.

As there is no shelving here the logger was placed on the floor and close to the wall.

It could be argued that, as there are no specimens in the immediate vicinity, this exercise could be regarded as irrelevant or trivial. However given that air circulates around the stores, any point that appears damp does have the potential to affect all parts of the store.

As a possible source of damp air it was regarded as important to monitor.

The readings at the NE Corner of the Petrology store were found to be the highest yet detected, see Figure 28.

Although the environment is slightly different at all the locations, the curve of the readings when plotted out generally follows a similar shape: peaks and troughs can be identified at each location at similar times, see figure 21. However, the humidity at this location did not follow the shape of the other loggers.

This gave rise to the suspicion that this area was being influenced by other phenomena not present at the other locations.

Interrogation of the data showed that the weather could be the major factor and that it was influencing this area more than others. The evidence pointed towards this area having a problem the others did not and that it should be investigated.

The graph of the data from the NE Corner has been provided as a transparency to allow easier comparison with the weather data from the same period given as Figure 27.

#### 3.4.3.1 Event 3: Discussion

Unfortunately due to the loss of data at a significant period between points 1 & 2 on Figure 28 it cannot be said if the problem started earlier than was detected. However, it can be seen that the humidity at the NE Corner has increased at point 2 whereas at the other logger locations it has decreased, when compared to point 1.

Between points 2 & 3 the NE Corner remains generally level, whilst the other loggers show a general downwards trend.

The increase, compared to the other loggers, in the humidity and corresponding drop in temperature at point 2 was noted to have taken place around the same time as the weather deteriorated. This was taken to mean that either air from the outside was influencing this area more so than at the other locations or that water had infiltrated the area.

This was confirmed when the humidity at the other locations decreased but continued to increase in this corner, point 3. The humidity level of the NE Corner increased beyond that of outside at point 3 and remained higher until the end of December. This led us to believe that water has infiltrated the store and was not dispersing; we had a ‘ponding’ effect.

A quick survey of offices above the store was carried out but nothing to identify the cause of the increased humidity levels was found, neither was there a sign of increased humidity or water ingress. It was commented however, that the office was thought to be humid by the occupants and therefore a de-humidifier runs continuously to protect computers and drawings.

On inspection of the outside of the building, mould was noted to be growing around the corner and a decorative feature was thought to have broken brickwork.

This was brought to the attention of the head of Facilities Management for Murchison House and a builder was arranged to inspect the area. It was found that the feature was faulty and the builder was instructed to affect repairs.

As this feature is present on a number of other corners of Murchison House, including the Palaeontology store, these were also examined. It was found that the problem was not unique to the NE Corner. Repairs were carried out as necessary on December 10th, point 4.

It is possible that the initial reason for commencing the monitoring programme was not due to the suspected vent but water ingress from a similarly defective decorative feature to the one found on the Petrology store.

There has not been a major improvement in the environment of the NE Corner since the 10th December when the external works were carried out. The humidity has remained higher than the other locations, although it has decreased to a level analogous with the external values.

Several peaks were mirrored in all locations although less so in the NE Corner, possibly due to the high base level. This was expected, as the water that had penetrated the cavity and brickwork will take time to dissipate.

The area will continue to be monitored to determine when, or if, the environment begins to resemble that of the other locations.

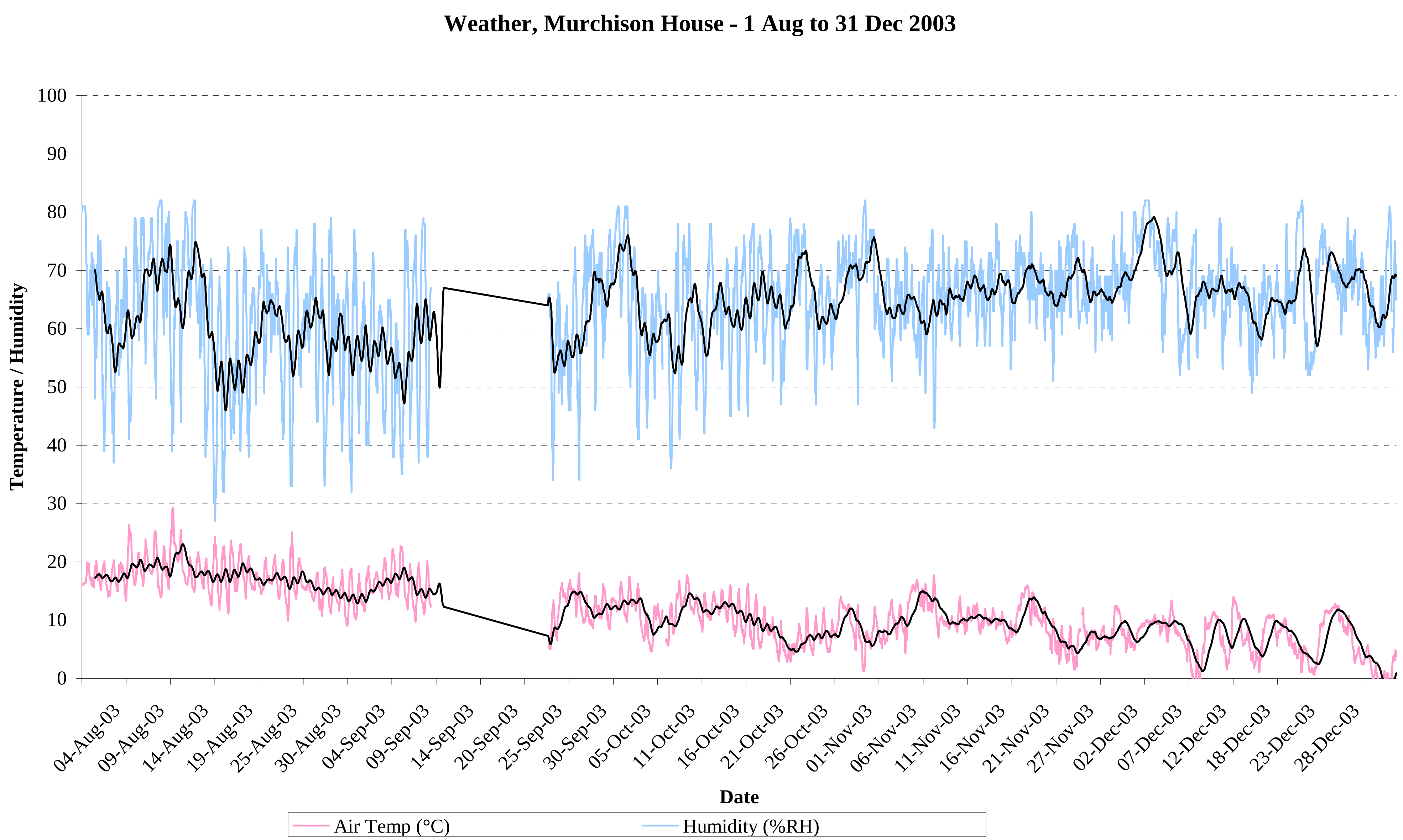


**Figure 27: Murchison House Weather Aug – Dec 2003**

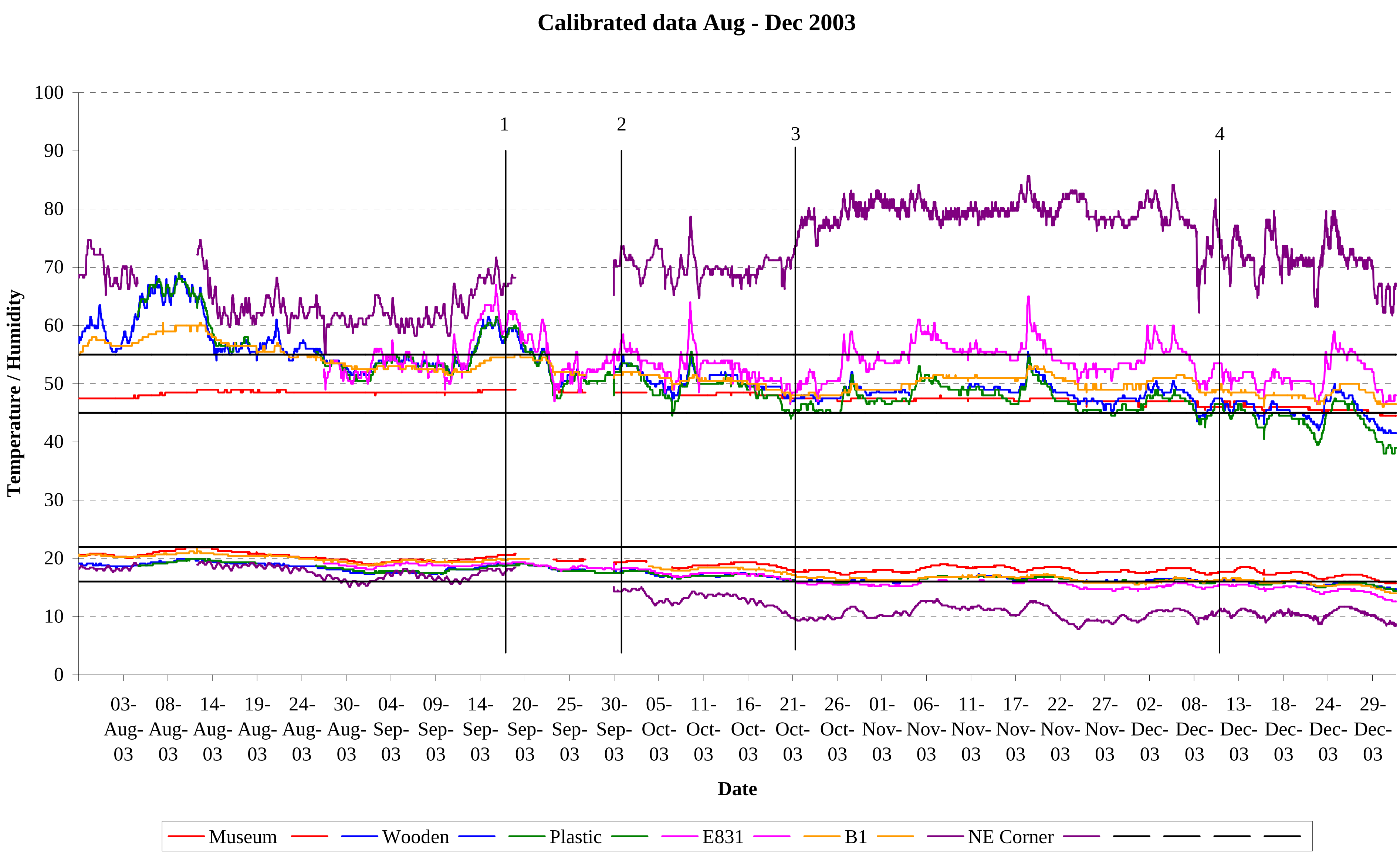


**Figure 28: NE Corner, Murchison House**

### 3.4.4 Future Mini Projects

#### 3.4.4.1 Microenvironments

The events discussed in the previous chapters highlights the need to monitor all environments, whether macro or micro.

One of the recognised methods to stabilise specimens and slow or stop the advance of decay is to store them in controlled microenvironments.

Generally when a specimen is sealed in a container a humidity-absorbing agent, for example Artsorb or Silica Gel, is also added to remove the moisture from the air.

This process is normally only carried out on specimens deemed 'at-risk' due to the expense of both the air-tight containers and the humidity-absorbent. There is also an increase in the amount of space required to store a large number of sealed containers.

Medium-scale protection has been carried out by completely sealing stand-alone cupboards. Again, this can be time-consuming, expensive and it is difficult to gain access to the specimens once sealed.

As has been identified in a previous chapter, wooden trays are very good buffers to external changes in humidity. If the conditions within the tray are good then a wooden tray is the best 'container' for specimens. However, problems arise if the trays get wet as the same principle applies to the environment inside the tray. The good buffering qualities of the wood does not allow the moist air to dissipate and it remains in the tray, potentially damaging the specimens.

The use of a damp meter to check the amount of moisture in wooden boxes may quickly identify problem areas and allow swift remedial action to be taken. This will be tested over the next 12 months.

#### 3.4.4.2 Continued Monitoring of 'Problem Corners'

The areas identified as damp due to faulty external brickwork will continue to be monitored until the environment is seen to return to a more normal level.

Associated with this monitoring will be the heightened inspection of the fabric of the stores. Internal cracks and holes will be filled as they are discovered and greater importance will also be given to examining the external structure.

#### 3.4.4.3 Monitor Differences in Open and Closed Aisles

All of the racking in the Petrology store and most of the racking in the Palaeontology store is high density mobile racking. The racks are pushed apart by means of hydraulic rams, opening one open aisle and closing another.

It is presumed that the movement of air around trays alters as aisles are opened and closed. What is unknown at this time is what effect this has on the specimens in the trays.

When more loggers are available a comparative study between two adjacent aisles will be carried out. The movement of the racks will be monitored and the data examined to determine if there are benefits in keeping the racks open or closed.

### 3.5 RECOMMENDATIONS FOR EDINBURGH

Additional loggers are required to extend the system. The present loggers will remain in place and the new loggers used as 'trouble-shooters'. Areas identified, or suspected, as being problematic should have a logger placed in them to monitor the conditions for a limited time to determine the condition of the environment and, therefore, action to be taken to rectify any problems.

This rationale will also be used for rooms being used as temporary stores. 'Mobile' loggers will be placed in them prior to data or samples. The measurements will be downloaded and interrogated as the area is being occupied and the loggers replaced and monitored for changes over the time of occupancy.

A damp meter should be purchased to measure the moisture of wooden trays at the time of discovery of pyrite decay or efflorescence. Measurements should also be taken at regular intervals and a mobile temperature & humidity logger should be placed in the tray to monitor changes. Trays in the immediate locality should also be measured.

Gathering data of this type will allow a record of measurements to be built, increasing our knowledge of the environments of the stores and the trays in which samples are stored. This in turn could allow us to identify conditions where specimens are at greatest risk and take action to reduce, or stop, deterioration occurring before it has advanced too far.

It is of advantage to both projects that we work closely with Facilities Management to identify shortcomings in building fabric and arrange repairs. This has proven successful in 2003 and it is vital that this continues.

# 4 Conclusion

### 4.1 CONCLUSION FOR KEYWORTH

The environmental monitoring at Keyworth over the last two years has shown fluctuations in temperature and humidity. These readings apply to the main storage areas, such as the core store and museum, where values have been outside the recommended parameters for the majority of the time. This shows such locations are not ideally suited for the storage of the collections. Considering the size of these areas, maintaining these ‘ideal’ conditions could be difficult or ineffective. Currently it is inconclusive as to whether the external weather conditions are also having an effect on these storage areas. The only exception seems to be during the summer months, when external humidity levels are often higher, or during periods of high precipitation.

A selected number of storage containers have been monitored in the same manner the results have shown more constant values throughout the monitoring periods concerned. Such containers are therefore more ideally suited for the general storage of specimens, however conditioned microclimates should be used for the storage of more sensitive materials.

The continuation of this environmental monitoring programme is essential for preservation of the materials held within Corporate Collections. This can only be achieved and developed upon by the use of the existing and additional monitors together with the knowledge attained from previous years.

## 4.2 CONCLUSION FOR EDINBURGH

The Collections are housed, in the main, in rooms ill suited and under equipped for the task.

Neither the Palaeontological or Petrological storerooms have an ideal environment for storing sensitive geological specimens. The rooms have no heating and, as a consequence, there are fluctuations in both the temperature and humidity of both rooms; neither meets the suggested parameters for specimen storage.

The programme of monitoring the temperature and humidity is vital to the safe keeping of the specimens.

The heightened awareness of staff and the results from the monitoring programme has proved to be valuable in identifying defects to the building and working practices that could detrimentally affect the Collections; repairs have been made and working practices updated which has led to an improvement in the conditions in the rooms concerned.

The museum cabinets in the Palaeontological store are very stable due to their construction; they are manufactured from mahogany and the drawers are covered and sealed behind doors. However, it was identified early in the monitoring programme that the simple step of opening the adjoining door to the general store caused the air to circulate better reduced the build-up of heat and humidity and created a better environment.

This was the first success and showed the advantages of the monitoring programme.

The programme of environmental monitoring is important to the preservation of the Collections and should be continued. Without a high level of expenditure on air-conditioning equipment this is the best way in which to monitor improvements to the storerooms. The current system and suite of loggers, meters and other recording instruments should be augmented by the purchase of additional loggers and damp meters.

Improvements to the stores have been made and will continue to be made in conjunction with the Facilities Management and this will be reflected in the data recorded.

# Appendix 1 Summary of the Strategy for Environmental Control

STRATEGY

1. Determine from appropriate sources (publications, meetings, personal communications, internal research, etc.) current best practice guidelines for the storage of the various materials types found within the NGMC. The guidelines should include the range and permissible variation of ambient temperature and of ambient relative humidity.

2. Routinely monitor temperature & Relative humidity in all storage areas, including conditions within typical trays, drawers, boxes and cabinets. Monitor external weather conditions where possible.

3. Review effects of room temperature and humidity on container temperature and humidity. Where the latter vary outside target limits, consider whether improvements can be made in the room parameters. Where temperature and/or Relative humidity readings indicate building/heating/ventilation defects, advise appropriate authorities.

4. Where trays or drawers vary outside these limits, microclimates must be used.

5. Implementation priority must be given to Museum Collection fossils and new borehole material.

PROCEDURES

Acceptable Temperature & Relative Humidity limits

1. Acceptable storage conditions for geological specimens (Doughty & Brunton, 1993)

| | | |
|---|---|---|
| Pyrite & Maracasite | 16-22°C | <55% |
| Sub fossil bone, tusks, teeth | 16-22°C | >40% |
| Fossils with shale/clay matrix | 16-22°C | >40% |

Storage Guidelines

2. All items should be stored in closed containers whenever possible.

3. Where pyritised fossils are to be stored in containers where humidity's may rise over 55%RH, they should be kept in microclimates, buffered with artsorb to 40%RH.

4. All pyritised fossils that have suffered pyrite decay should be stored in microclimates, buffered with artsorb to 40%RH.

5. Fresh borehole material, where organic or sulphide content is important, should be stored in barrier film, with Oxygen scavengers, in the cold store at 4°C.

Monitoring Guidelines

6. Monitor temperature and relative humidity readings on a regular basis, i.e. every 3 minutes, starting on the hour.

7. Monitors should be downloaded into a suitable digital format on a weekly basis.

8. Where possible, monitors should be calibrated on a regular basis, i.e. once a year, or when new loggers are purchased, so they can be used as a benchmark.

# Appendix 2 Keyworth Data

Adobe® Acrobat® version of this report.

<u>Three folders containing: -</u>

<u>Raw Data</u>

- 2 Main Sub folders, one for each year (2002 & 2003)
    - For each year there is a folder for each type of monitor in each location.
    - Each folder contains raw data in Comma Separated Value (.csv) format (readable by MS Excel).
    - Each folder also contains raw data in original format as downloaded from loggers (.lcf format).
    - Please note downloaded data from the Casella is in .dat format and ThermoHygrograph and weather data are in MS Excel format.

<u>Calibration Data</u>

- Data used for calibration test prior to calibration
    - Raw data in Comma Separated Value (.csv) format (readable by MS Excel).
    - Raw data in original format as downloaded from loggers (.lcf format), ThermoHygrographs in MS Excel format.

- Data used for calibration test after calibration in MS Excel format

<u>30 Minute Extracted Data</u>

- 30 minute extracted data in MS Excel format for 2002
- 30 minute extracted data in MS Excel format for 2003
- Histogram extracted data in MS Excel format for 2002
- Histogram extracted data in MS Excel format for 2003

# Appendix 3 Edinburgh Data

Adobe® Acrobat® version of this report.

<u>Four folders containing: -</u>

<u>2002</u>

- Calibrated/GMT adjusted data for the year in MSExcel format.
- ‘Mini Project’ graph
- Converted Files
    - Raw data in Comma Separated Value (csv) format (readable by MSExcel).
- Logger files
    - Raw data in original format as downloaded from loggers (lcf format).

<u>2003</u>

- Calibrated/GMT adjusted data for the year in MSExcel format.
- ‘Mini Project’ graphs
- Converted Files
    - Raw data in Comma Separated Value (csv) format (readable by MSExcel).
- Logger files
    - Raw data in original format as downloaded from loggers (lcf format).

<u>Access Files</u>

- All environment data.mdb - Store room data
- MH Met data.mdb - Weather station data

<u>Met Data</u>

- One text file explaining the data format of the files.
- 2003
    - Calibrated data for the year in MSExcel format.
    - 9 folders containing data from Weather Station in original format (Raw) and MSExcel format (Splits).

# Glossary

BGS - British Geological Survey

BST - British Summer Time

CSV - Comma Separated Value (file) .csv

GMT - Greenwich Mean Time

LCF - Logger Compact File .lcf

NGRC - National Geological Records Centre

RH - Relative Humidity

MTA - Murchison House Weather Station, Temperature readings, .MTA

MHU - Murchison House Weather Station, Humidity readings, .MHU

# References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.


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