EXARC Journal 2019/2
23 Articles | Open Access

Reviewed Article:

Going Underground: An Experimental Archaeological Investigation of an Early Medieval Irish Souterrain

Persistent Identifier: https://exarc.net/ark:/88735/10425

EXARC Journal Issue 2019/2 | **Publication Date:** 2019-05-21

Author(s): Tom Meharg [1]

[1] Independent researcher, 29 Dundrod Road, Nutts Corner, Crumlin, Co Antrim, Ireland.

During the summer of 2018 I completed a master's degree in experimental archaeology and material culture at University College Dublin, this research was carried out for the final dissertation. The project was to build and test a 1:1 model of an early medieval Irish souterrain. The subterranean structure is based on one of over 3,500 examples of this feature identified in Ireland. The project allowed us to interact with the similar problems likely facing past societies in regards to design and engineering. Furthermore, by building such a feature

we could engage with a souterrain as it may have existed in the early medieval period allowing interesting discussions on the experiential aspects of structure. The souterrain acted as an experimental space where I could investigate the food storage hypothesis by testing environmental conditions relating to the storage of certain foodstuffs. The results show that throughout the test period the model souterrain could maintain a constant internal temperature and humidity level most preferable for long term storage of some dairy products, root vegetables, and some fruits.

> “The results from these tests record only a small period time, and to get any meaningful information on long term environmental conditions would require a long term experiment. However, this pilot test does raise some interesting questions and insights to the possible use of a souterrain as a food store.

Introduction

The souterrain is a common feature of the early medieval period in Ireland with over 3,500 examples identified (O’Sullivan *et al*. 2008, 86). The earliest of these date from the mid first millennium AD, with the majority occurring between the ninth century and the arrival of the Anglo Normans in the twelfth century (Clinton 2001, 92). Most of these subterranean structures exist as stone built passages and chambers constructed in a pre-formed trench and covered with earth. Examples of souterrains built using both timber and stone, or solely timber, are also present, however, due to the nature of survival and discovery it is likely that these forms are underrepresented archaeologically (*ibid*, 11). Other than being a manmade, underground space, souterrains vary considerably in shape and style.

Typical interpretations of their function fall into three categories. One is a storage facility, first suggested by the eighteenth century antiquarian Thomas Molyneux (1725, 209) “They must have been contrived for the convenient disposal of arms and provisions... under such a guard that kept them safe from thief and enemy.” A secondary purpose is as a refuge as suggested by William Beauford (1789, 83-5) claiming it was a structure “into which they retreated in time of danger”. The third is dual purpose where the souterrain is a store and a refuge. The majority of academics follow this interpretation, with many choosing a primary function of either refuge or storage. Mark Clinton’s (2001) book: the souterrains of Ireland is the most comprehensive study of souterrains with a strong focus on distribution, function, and structural aspects. His interpretation of function is that complex examples are for refuge and small, simple, souterrains are cold storage (*ibid*, 17). With several thousand souterrains each varying in form, it is difficult to make any meaningful overarching descriptions. A more valuable approach would be investigating souterrains on a case by case basis (O’Sullivan *et al*. 2013, 111).

Although such previous research has been incredibly valuable for understanding the souterrain as an archaeological feature, it is difficult to assess how it would have functioned. Over the passage of time internal doors will have rotted, passages and air vents will have silted up and the souterrain will no longer act as it did when it was in use in the early medieval period. This is why I decided to approach the subject through experimental archaeology. My major research focus was the suitability of a souterrain as a food storage facility; to test this hypothesis a new souterrain had to be built. By modelling it on an archaeological example, I could experience and test the conditions within a space that paralleled a souterrain that existed in the early medieval period.

For the purposes of this research, I chose to replicate a simple timber framed souterrain from a recent excavation of a high status early medieval settlement at Knockhouse Lower, Co. Waterford (Walsh 2017). This multi banked and ditched enclosure, or rath, dated to the mid seventh to mid eighth centuries AD (*ibid*, 46), is a common feature of the period representing the dwelling place of a high-status agricultural family along with slaves, servants and fosterages (O'Sullivan *et al*. 2013, 41). The excavated souterrain had minimal alteration to the original cut whilst the report had detailed plans and comprehensive environmental samples allowing my model to best represent an archaeological example. Ulf Näsman (2013) argues that archaeological reconstructions must be based on a wealth of contemporary structures in order to identify general characteristics. With that in mind several comparable souterrain excavations were studied to inform this model (see Cleary 2015, 276-86; Ó Riordáin 1939; Ó Riordáin and Dermott 1951; Stenberger 1966; Williams 1985)

The creation of the souterrain allowed me, and those assisting, to engage with digging techniques, structural joinery, and wattle weaving. Although our experiences do not represent those of past agricultural societies, some valuable insights were identified. Likewise, experiencing the finished souterrain, as it would have existed in the early medieval period informed interesting discussions on lighting, and moving through the feature. The completed structure also acted as an experimental space allowing the testing of internal environmental conditions, specifically temperature and humidity, which would be an issue for food storage. It is not the intention of this research to make any final call on souterrain functions, instead it provides way in which to study such a feature and highlights future directions of study.

Methodology

Initially the souterrain was designed and plotted to scale based on the descriptions, plans, and photographs of 'Souterrain two' at Knockhouse lower (Walsh 2017, 73-6; 266-7). The major alteration to the original excavated example was the addition of several postholes, to ensure a solid structure without changing the morphology of the souterrain. The design process is illustrated in Figure 1. A cut feature at the back wall was interpreted as an air vent, these are common features of souterrains and appear in numerous excavated examples

(Clinton 2001, 25). It was decided that modern tools would be used for the excavation of the construction trench, this was an issue of both health and safety and efficiency in the limited timeframe of the project. Although early medieval timber souterrains would have likely been constructed with oak or ash (*ibid*, 36; Williams 1985, 48) it was decided that pre-cut structural timber would be used for the construction. This was a decision made due to cost, safety, and time, highlighting how real life limitations can influence a project. This research is focused on creating an experimental space that best represents the conditions within a souterrain, and I believe the concessions made were appropriate. A useful outcome of future experimentation would be assessing the difference between this souterrain and one constructed entirely from native green wood.

Although there are no archaeological examples of the joinery used in early medieval timber souterrains, inspiration was gained from excavated remains of bridges and mills surviving in waterlogged deposits (Geaney 2016, 90-1). Simple mortice and tenon joinery is present and it is likely such methods were used in souterrains. Guidance on the woodworking was sought from Terry Runner, a fellow master's student with a professional background in carpentry, Ulf Nässman (2013) highlights the importance of obtaining advice from people with both expertise in their craft and an understanding of the processes of experimental archaeology.

The actual creation of the 1:1 model souterrain is discussed in the results and discussion section. With the experimental space completed the environmental conditions could be tested.

The assessment of internal conditions was originally intended to last a month, however, due to the longer than expected construction phase the experiment lasted just under two weeks starting on the 24th of July 2018 and finishing on the 6th of August 2018. The temperature was recorded at four locations using thermocouples connected to a digital data logger (See Figure 2). The first was outside the entrance to assess external conditions so comparisons could be made with the internal temperatures. The second was in the entrance passage section where natural light would enter the souterrain. The third was in the mid passage section where natural light was no longer an issue. The fourth was in the chamber, the area interpreted as a storage space.

The humidity was recorded in the chamber (See Figure 2), this sensor measured temperature, relative humidity, and dew point. Relative humidity is important in many food storage systems and relates to the moisture in the air whilst the dew point is the temperature at which condensation occurs. These conditions would indicate the suitability of the souterrain as a food storage space.

Temperature and humidity levels were recorded every 10 minutes for three test periods in order to assess the impact of doors in the souterrain. The location of the sensors is shown in Figure 2.

Test 1 July 24th - July 27th 2018:	During this phase the internal door at the passage chamber junction was left open.
Test 2 July 27th - August 2nd 2018:	The door was closed at the chamber passage junction in order to test the function of the door and the implication of this on internal conditions.
Test 3 August 2nd – August 6th 2018:	The entrance to the souterrain was also blocked. This would prevent natural light from entering the souterrain.

Results and discussion

Building and experiencing the souterrain

The process of building the souterrain can be broken down into three sections, the first is the excavation of the trench, next is the construction of the souterrain structure in the trench, and the third is burying the structure. This process lasted for a month, it should be noted that this was much longer than anticipated due to access restrictions and availability of help. The actual labour time better represented fourteen full working days with perhaps one or two assistants.

At the UCD centre for experimental archaeology and material culture an area was decided upon and cleared of topsoil, the outline of the souterrain was then plotted (See Figure 3). The arduous process of digging the construction trench followed. An unexpected aspect of this phase was the difficulty of excavating the boulder clay subsoil. Spades and shovels easily removed the topsoil but were useless in the hard packed earth beneath. The most efficient method of excavation was achieved by digging a deep channel with a pick and then using a crowbar to collapse the sides (See Figure 4) this method was utilised for the entirety of the excavation phase. In total 18m^3 of spoil was removed from the trench along with 2m^3 of stones.

Although modern tools were used for this process archaeological excavations at Killickaweeney, Co. Kildare, show evidence of how such tasks were undertaken in the early medieval period. The ditch fill of a rath settlement at this site returned two antler picks with heavy use wear on the tips of the tines (Carlin 2008, 48). Out of experiential interest, I tested the effectiveness of an antler pick for excavating boulder clay (See Figure 5). It was surprisingly effective having similar qualities to the small metal hand pick we were using. A souterrain trench could have been excavated in a similar way to ours using an antler pick to dig a narrow channel, and then hammering wooden stakes into the side to collapse the edge. This would explain the scarped sides on the archaeological example from Knockhouse Lower (Walsh 2017, 266).

The time taken to excavate the souterrain trench cannot be used to suggest likely excavation times for early medieval people. As an agricultural society well accustomed to contemporary digging technologies, projecting modern attitudes and ability into the past is ineffectual (Reynolds 1999, 158). Instead, societal implications may be explored. We believe that excavating a souterrain trench would be best suited to late spring to early summer. With cattle out to pasture and the year's crops sowed, the time away from the land in the drier weather would provide suitable conditions for such an undertaking. For my project, I was lucky to receive the help of numerous classmates who took time from their own research to swing picks in the hot sun and shovel numerous buckets of earth. It is likely that the souterrain at Knockhouse Lower would have been completed by the head of family with the assistance of household slaves or servant. Kelly (1998, 444) identifies the profession of *cladaire* or ditch digger listed in early medieval texts. Although this likely references the construction of larger defensive ditches surrounding homesteads, it is possible that itinerant labourers were involved in such tasks.

With the trench excavated the timber structure was constructed in situ. Postholes were cut into the earth and posts were secured with packing stones (See Figure 6). Parallel roofing beams were then connected to the posts using mortice and tenon joints (See Figure 7). Structural roofing boards had notches cut into them and were slotted over the parallel roof support beams to prevent lateral movement (See Figure 8).

Willow wattle was then weaved between the timber frame and the trench to act as a retaining wall (See Figure 9). In the hot weather, the willow became brittle and it was difficult to complete many of the sharp corners in the souterrain, fresh coppiced willow would be ideal for such work. At the air vents and the entrance, a stone and clay revetment was built to prevent backfill from falling into the souterrain. The loose boulder clay was then poured into the cavity between the wattle and the trench wall (See Figure 10), surprisingly very little slipped through the gaps in the wattle. Finally, the entire structure was roofed and buried leaving a stepped entrance at the front and an air vent above the chamber (See Figure 11).

In stone built examples of souterrains, building materials are sourced locally from the surrounding land (Clinton 2001, 8). It is also apparent from archaeological examples that large lintel stones for the roofing were harder to come by; some souterrain roofs incorporate recycled grave slabs and ogham stones (*ibid*, 92). Timber, framed or composite stone walled and timber roofed souterrains are likely a result of lack of building materials. The rarity of timber examples in the archaeological record could be an issue of discovery. Buckley (1986, 109) identified settlements with 'L' or 'T' shaped depressions in the earth in several counties devoid of stone souterrains, these should be properly investigated as a collapsed timber example would leave such a trace.

When interacting with the finished souterrain some interesting insights were gained. The space was constricted and there was no room to turn in the passage so once inside, individuals had to crawl to the chamber and turn. All participants admit to a certain feeling of claustrophobia in the structure. The chamber had a maximum capacity of three individuals, anything more became cramped and uncomfortable. Sunlight entered the souterrain from the entrance (See Figure 12), however, beyond the bend in the passage artificial lighting was required. The light of several candles was sufficient for any activity carried out in the souterrain, figure 13 shows the setting up of sensors by candle light.

It is impossible to experience this souterrain as an early medieval person would have; we can only recognise what we ourselves feel in the space. We all agreed that it would not have been our choice as a refuge in a time of violent attack. We also discussed how being down in the dark and cramped conditions gave a sense of being trapped rather than any form of safety. It would be easy for an attacker to light a fire at the entrance or fill it with earth to suffocate us. Such incidents are referenced in early medieval texts, in *The war of the Gaedhil with the Gaill*: "...Muchdaighren, son of Reachtabrat, was suffocated in a cave [understood as a souterrain]." in the year 852 AD (Lucas 1971, 184). An air pollution test would be a very interesting experiment to see if this was possible. From the experience of those who entered the souterrain it was unequivocally decided that we would not take refuge in the Knockhouse Souterrain Two.

Testing the internal conditions of the souterrain

The souterrain maintained a steady temperature and a high relative humidity throughout the course of the three tests, in the chamber, where items were likely to be stored, temperature averaged between 16˚C and 17˚C whilst relative humidity typically sat between 95% and 100%. It should be noted that due to a problem with the battery life of the data logger some periods of the test were lost. Having a permanent power source to the experimental site would allow more consistent results for future testing. The results of the three tests are presented in Charts 1-6 the full dataset will be kept for a period of four years for any future investigations.

During test one (See Chart 1 and 4), with no internal door present, the temperature in the entrance portion of the passage (T2) saw the greatest range as sunlight entered the feature. Deeper within the souterrain at the chamber location (T4), the temperature fluctuated slightly sitting at 18˚C during the day, and dropping to 16˚C at night. Comparing this to the day and night ranges recorded by the external thermocouple (T1) the souterrain was successful at reducing the effect of temperature change and was able to maintain steady environment. The humidity levels during this test had day time averages between 91% and 97% rising and falling considerably, as much as 16% and no less than 5%.

During test two (See Chart 2 and 5), with a door closed between the passage and the chamber, the chamber temperature ranges between day and night were not as apparent. The overall average during this phase was 16˚C in the chamber and the range between maximum and minimum values was smaller than the previous test. In the entrance portion, the effect of external conditions was still visible in the recorded temperatures. Like the stabilisation in temperature, the relative humidity recorded in the chamber was reasonably stable. Similarly the average day and night time relative humidity values remained between 96% and 100% throughout the test. The average temperature comes very close to the dew point but remained below it for the majority of the test meaning condensation was not likely to occur for any considerable period.

With a second door placed at the entrance of the souterrain, test three (See Chart 3 and 6) saw the most consistent temperatures throughout the structure with and average temperature of 17˚C in the chamber ranging no more than 1˚C between during this phase. External factors had less of an effect on the entrance portion as this was now blocked. The relative humidity recorded in the chamber was higher than the previous two tests, sitting consistently at 99% to 100% both day and night. Along with the stabilisation in temperature sitting at the dew point, condensation would occur in such conditions.

The results from these tests record only a small period time, and to get any meaningful information on long term environmental conditions would require a long term experiment. However, this pilot test does raise some interesting questions and insights to the possible use of a souterrain as a food store.

Studying both source material and archaeological records, aspects of the social importance of diet and food production of early medieval Ireland can be seen. The dietary staples of this period were grain and dairy, supplemented with vegetables and meat. Finbar McCormick (2013, 121-2) has identified numerous archaeological sites where faunal remains show patterns consistent with dairying communities. Typically bones of young male and elderly dry female bovine are abundant, with lesser quantities of pig (*ibid*, 122). Grains are seen in archaeobotanical remains often surviving archaeologically as charred samples resulting from cooking or drying processes (McCormick *et al*. 2011, 46). Evidence for fruit and vegetables is less common; however, their importance is listed in numerous contemporary written sources (Kelly 1998, 253-71). Likewise, the importance of dairy products, difficult to assess archaeologically, is most visible in texts (*ibid*, 323-9).

Many of these foods are seasonal and numerous methods of preservation are required to keep provisions for the winter months. Grain drying kilns, abundant in the archaeological record, are an example of one method (McCormick *et al*. 2011, 33). Likewise, references to salting and curing pork are present in early texts (MacNeill 1921, 291). Cheese and butter production are also significant, seven forms of cheese are discussed in source material ranging from the soft semiliquid *Millsén* to hard pressed *Tanach* (Lucas 1960, 22-3). The suitability of the souterrain for long term storage of any of these food sources relies on their own specific requirements. For example, the high humidity within the souterrain is unsuitable for the storage of dried grain or cured pork (Strelec *et al*. 2010, 20; Andrés *et al*. 2007, 43). Granaries found archaeologically and mentioned in texts would be suitable for grain storage (McSparron *et al*. 2009, 131). For pork, the law tract *críth gablach* outlines for the noble social grade of *bóaire* or cattle lord, one of the requirements is "a bacon pig on a hook" (MacNeill 1921, 291). The smoky, drier conditions within a round house would be suitable for this.

The main food groups that would suit conditions similar to those recorded in the souterrain would be butter, cheese, and some fruits and vegetables such as onions and apples. The primacy of dairy products at this time raises interesting questions on storage, cheese ripening can be achieved in temperatures between 7 ˚C and 21˚C as long as a constant temperature is achieved (Sennett 2017, 124). Humidity is also important; the process requires a relative humidity of 75% -99% and regular renewal of air. Test two, with one internal door, showed conditions that would be complimentary to cheese ripening. Downey and Stuijts (2013, 122) have previously stated that a souterrain would be too warm to store butter. However, early medieval butter was stored wrapped in bark (Kelly 1998,324), a similar practice is seen for some cheese manufacture in the Alps. Here the dairy products are wrapped in bark, which promotes the growth of bacteria beneficial to the ageing process, preventing microbial spoilage (Gibbons 2017, 59).

Although the research conducted here can only show that through the test period the souterrain had an internal environment suitable for the storage of some food groups, certain directions for future research have been identified. A much longer internal environment test should be conducted. Assessing the conditions within the souterrain for a year would allow a better understanding of seasonal storage, especially in the autumn to early spring where food preservation was necessary. This should run in conjunction with actual storage experiments, foods should be stored in the souterrain to test the viability of this structure as a store. Likewise, different storage vessels should be assessed as they may prevent the detrimental effect of condensation.

Beyond Ireland similar forms of storage have been used throughout history, Clinton (2001, 175) identifies souterrains in north eastern Scotland, Cornwall, Brittiany and Jutland. Tacitus's 98 AD *Germania* (Tacitus, *Germania* 16) specifically references the Jutland examples. Here the Germanic tribes "are wont also to dig out subterranean caves... as a receptacle for the year's produce, for by such places they mitigate the rigour of the cold." (*ibid*) A full analysis of the available archaeological material relating to these sites and the wider dietary trends of these regions would lead to an interesting comparison. A general revival in souterrain studies is required, incorporating a multidisciplinary assessment of souterrains in Ireland and beyond.

A better understanding of what makes these structures unique will undoubtedly lead to new interpretations about their functions.

Conclusion

At the beginning of this project, the major research objective was relatively simple, create an experimental space based in an archaeological assessment and test the environmental conditions within. The actual engagement with the construction process, designing a souterrain, excavating the trench, and building the structure, highlighted considerations about how such a task was undertaken in the early medieval period. Whatever the intended use, the decision to build a souterrain was significant. A process that would have required the input of skilled and unskilled labourers orchestrated by individuals well aware of the engineering required to complete a reliably stable underground space.

The specific tests within the souterrain show that it successfully maintained a temperature ranging between 16˚C and 17˚C and a humidity of 95-100%. In regards to the food storage hypothesis, this research has shown that such conditions would be suitable for certain foods. However, it has also raised the importance of continued testing to build upon these preliminary results. Long-term storage experiments would show how these features may function at different times of the year. Furthermore, the sheer variance of souterrains in Ireland and abroad highlights the need to move away from generalising views of these structures. Fully assessing the souterrain in the wider context of European archaeology and experimental archaeology is necessary. Currently the souterrain is a neglected monument, but these features conceal a deep cave of information waiting to be explored.

Keywords construction of building

Country Ireland

Bibliography

Andrés, A., Barat, J., Grau, R. and Fito, P., 2007. Principles of Drying and Smoking. In Toldrá, F., ed. *Handbook of fermented meat and poultry*. Iowa: Blackwell publishing, pp. 37-50.

Beauford, W. 1789, *A Memoir Respecting the Antiquities of the Church of Killossy, in the County of Kildare; With Some Conjectures on the Origin of the Ancient Irish Churches*, The Transactions of the Royal Irish Academy, vol. 3, pp. 75-85.

Buckley, V., 1986. Ulster and Oriel Souterrains: An Indicator of Tribal Areas?, *Ulster Journal of Archaeology*, vol. 49, pp. 108-110.

Carlin, N., 2008. Killickaweeny 1: High-class early medieval living. In Carlin, N., Clarke, L., Walsh, F. & National Roads Authority, eds. *The archaeology of life and death in the Boyne* *floodplain: the linear landscape of the M4, Kinnegad-Enfield-Kilcock motorway.* Dublin: National Roads Authority. pp. 27-55.

Cleary, K., 2015. *Archaeological networks: excavations on six gas pipelines in County Cork*. Cork: Collins Press.

Clinton, M., 2001. *The souterrains of Ireland*. Bray: Wordwell.

Downey, L. and Stuijts, I., 2013. Overview of historical Irish food products—A.T. Lucas (1960–2) revisited, *Journal of Irish Archaeology*, vol. 22, pp. 111-126.

Geaney, M., 2016. Timber bridges in medieval Ireland, *Journal of Irish Archaeology*, vol. 25, pp. 89-104.

Gibbons, D., 2017. Bark-wrapped cheese. In Donnelly, C., ed. *The oxford companion to cheese*. Oxford: Oxford university press, pp. 59-60.

Kelly, F., 1998. *Early Irish Farming: a study based mainly on the law-texts of the 7th and 8th centuries AD*. Dublin: School of Celtic Studies.

Lucas, A., 1960. Irish Food before the potato, *Gwerin: A Half-Yearly Journal of Folk Life*, vol. 3 no. 2, pp. 8-43.

Lucas, A., 1971. Souterrains: The Literary Evidence, *Béaloideas*, vol. 39/41, pp. 165-191.

MacNeill, E., 1921. Ancient Irish Law. The Law of Status or Franchise, *Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature*, vol. 36, pp. 265-316

McCormick, F., 2013. Agriculture, settlement and society in Early Medieval Ireland, *Quaternary International*, vol. 346, pp. 119-130.

McCormick, F. Kerr, T., McClatchie, M and O'Sullivan, A., 2011. *The Archaeology of Livestock and Cereal Production in Early Medieval Ireland, AD 400-1100*. Early Medieval Archaeology Project Report 5.1, INSTAR.

McSparron, C., Williams, B. and Bourke, C., 2009. The excavation of an Early Christian rath with later medieval occupation at Drumadoon, Co. Antrim, *Proceedings of the Royal Irish Academy*, vol. 109C, no. 1, pp. 105-164.

Molyneux, T., 1725. A discourse concerning the Danish mounts, forts and towers in Ireland, in Boate, G., ed. *A natural history of Ireland, in three parts: By several hands. Part III*. Dublin: George Ewing, pp. 189-213.

Näsman, U., 2013. Aspects on Realizing House Reconstructions: a Scandinavian Perspective, *EXARC Journal* 2013, issue 2. Available at: https://exarc.net/issue-2013-2/ea/aspects-realizing-house- reconstructions-scandinavian-perspective [Accessed 15/07/2018].

Ó Ríordáin, S & Dermott, M., 1951. The Excavation of a Ring-Fort at Letterkeen, Co. Mayo, *Proceedings of the Royal Irish Academy*, vol. 54, pp. 89-119.

Ó. Riordáin, S., 1939. Excavations at Cush, Co. Limerick. (1934 and 1935), *Proceedings of the Royal Irish Academy*, vol. 45, pp. 83-181.

O'Sullivan, A., McCormick, F. Kerr, T. and Harney, L., 2008. *Early medieval Ireland, archaeological excavations 1930-2004*. Early Medieval Archaeology Project Report 2.1, INSTAR.

O'Sullivan, A., McCormick, F., Kerr, T., and Harney, L., 2013. *Early medieval Ireland, AD 400-1100: the evidence from archaeological excavations*. Dublin: Royal Irish Academy.

Reynolds, P., 1999. The nature of experiment in archaeology, in Harding, A., ed. *Experiment and design*. Oxford: Oxbow books, pp. 156-62.

Sennett, J., 2017. Cave, in Donnelly, C., ed. *The oxford companion to cheese*. Oxford: Oxford university press, pp. 124-6.

Stenberger, M., 1966. A Ring-Fort at Raheennamadra, Knocklong, Co. Limerick, *Proceedings of the Royal Irish Academy*, vol. 65, pp. 37-54.

Strelec, I., Popović , R. Ivanišić, I., Jurković, V., Jurković, J., Ugarčić-Hardi, Z., and Sabo, M., 2010. Influence of temperature and relative humidity on grain moisture, germination and vigour of three wheat cultivars during one year storage, *Poljoprivreda*, vol. 16, no. 2, pp. 20-24.

Tacitus. *Germania*. Translated by A. Church and J. Brodribb, 1942. In: M. Hadas, ed. *The complete works of Tacitus*. New York: Random House.

Walsh, F., 2017. Final report on excavations at archaeological area 1 at Knockhouse Lower, Co.Waterford. Dublin: *Irish Archaeological Consultancy LTD*.

Williams, B., 1985. Excavation of a Rath at Coolcran, County Fermanagh, *Ulster Journal of Archaeology*, vol. 48, pp. 69-80.

Corresponding Author

Tom Meharg
Independent researcher
29 Dundrod Road
Nutts Corner, Crumlin, Co Antrim
Ireland
E-mail Contact

Gallery Image

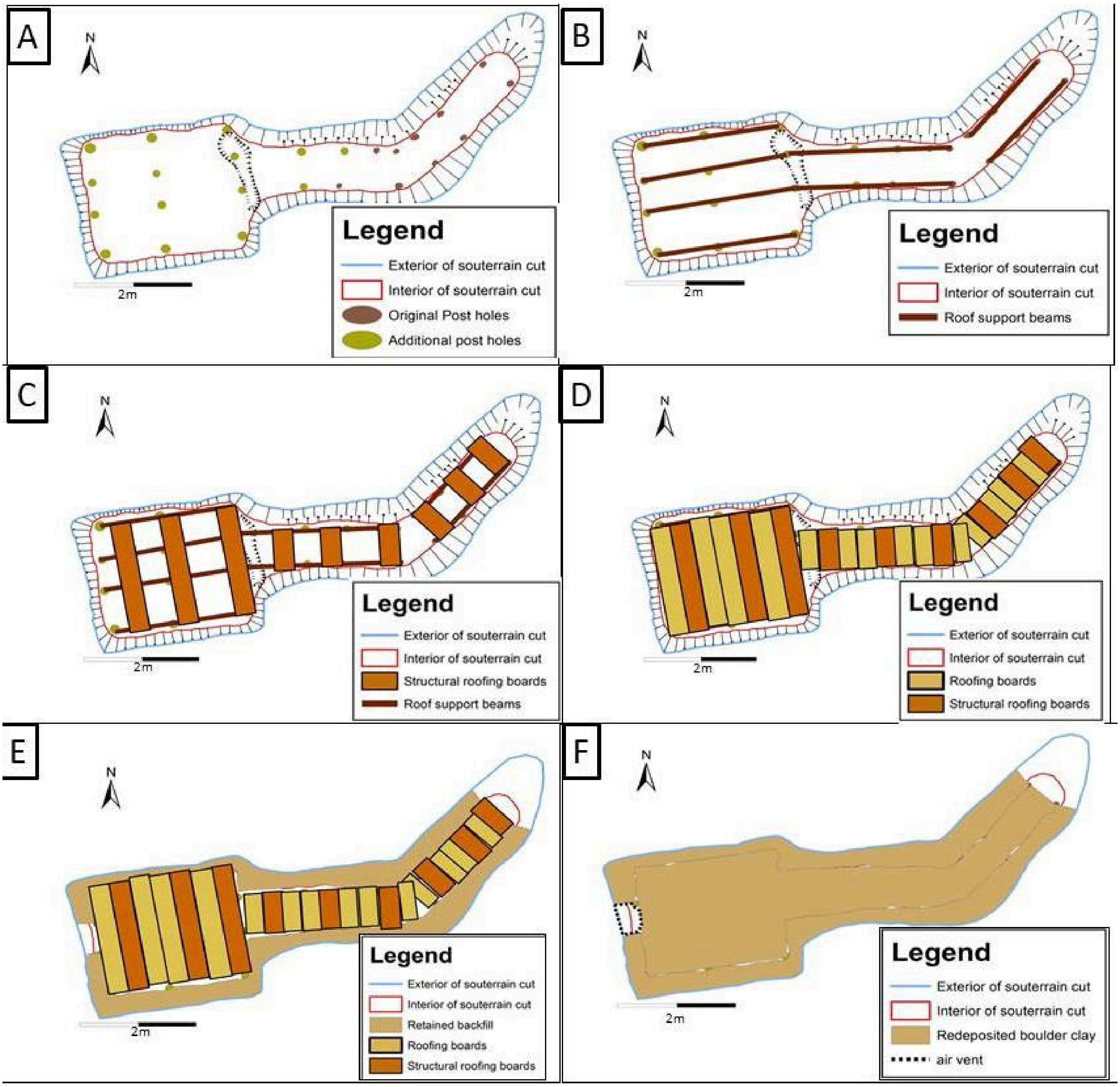

FIG 1. PLAN OUTLINING THE METHOD OF CONSTRUCTION OF THE SOUTERRAIN. A: LOCATION OF ORIGINAL AND NEW POSTHOLES. B: LOCATION OF ROOF SUPPORT BEAMS. C: ADDITION OF STRUCTURAL ROOFING BOARDS. D: PLACEMENT OF REMAINING ROOFING BOARDS. E: BACKFILLING TO THE WATTLE WALLS. F: BACKFILLING OF THE ENTIRE STRUCTURE. IMAGE BYTOM MEHARG

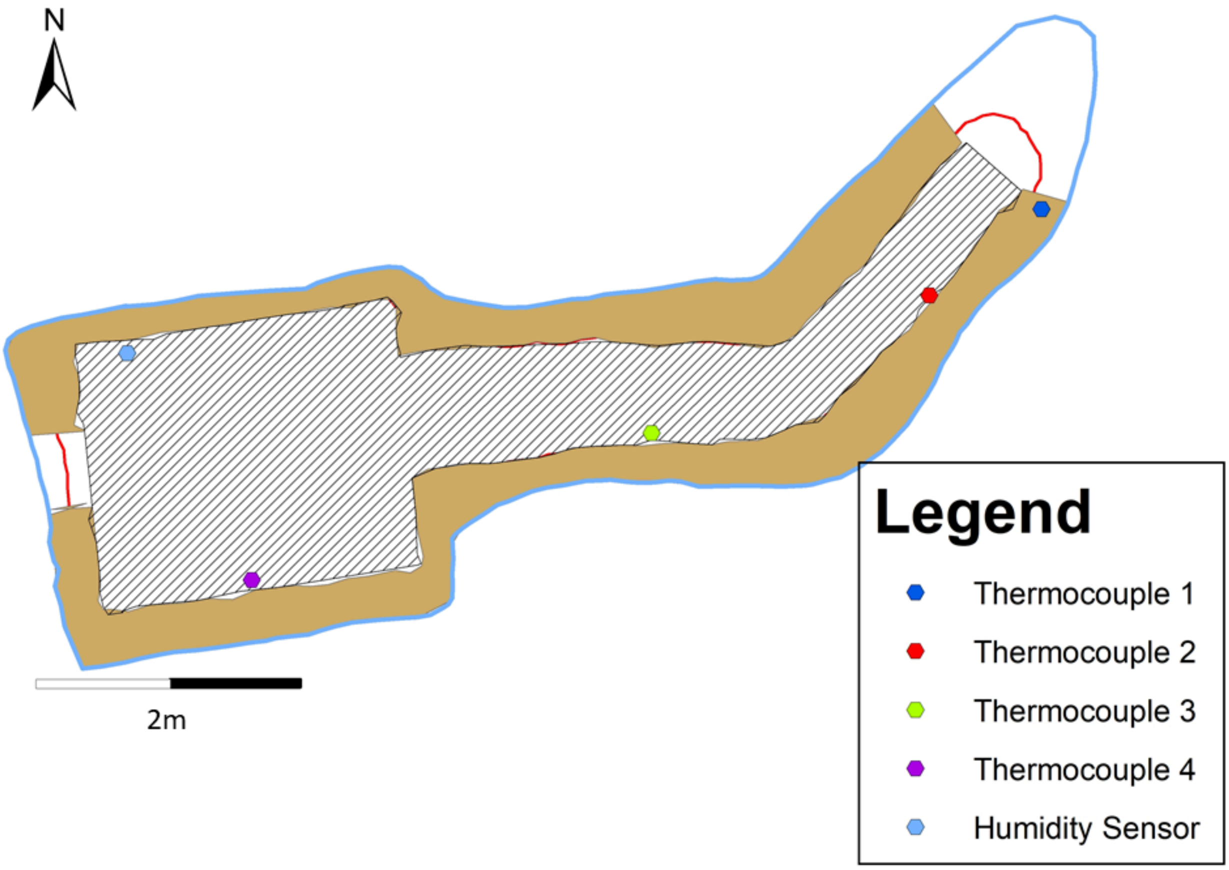

FIG 2. LOCATION OF SENSORS IN THE SOUTERRAIN. THERMOCOUPLES MEASURE TEMPERATURE, AND THE HUMIDITY SENSOR MEASURES PERCENT RELATIVE HUMIDITY AND DEW POINT. IMAGE BYTOM MEHARG

FIG 3. PLOTTING THE OUTLINE OF THE SOUTERRAIN AT UCD CENTRE FOR EXPERIMENTAL ARCHAEOLOGY AND MATERIAL CULTURE. PHOTO BY TOM MEHARG

FIG 4. EXCAVATION TECHNIQUE OF DIGGING A CHANNEL AND BREAKING DOWN THE EDGES WITH A CROWBAR. PHOTO BY TOM MEHARG

FIG 5. SHAPING THE CHAMBER WALL USING AN ANTLER PICK. PHOTO BY TERRY RUNNER

FIG 6. SECURING POSTS IN POSTHOLES WITH PACKING STONES. PHOTO BY TOM MEHARG

FIG 7. ADDING POSTS AND ROOFING BEAMS TO BUILD THE FRAME OF THE SOUTERRAIN. PHOTO BY TOM MEHARG

FIG 7. ADDING POSTS AND ROOFING BEAMS TO BUILD THE FRAME OF THE SOUTERRAIN. PHOTO BY TOM MEHARG


FIG 8. ADDITION OF STRUCTURAL ROOFING BOARDS TO SECURE SOUTERRAIN FRAME. PHOTO BY TOM MEHARG

FIG 9. WEAVING THE WILLOW WATTLE RETAINING WALL BETWEEN THE FRAME AND THE TRENCH WALL. PHOTO BY TERRY RUNNER

FIG 10. POURING THE LOOSE BOULDER CLAY INTO THE CAVITY BETWEEN THE WATTLE AND THE TRENCH WALL. PHOTO BY TOM MEHARG

FIG 11. THE SOUTERRAIN COMPLETELY BURIED WITH TOPSOIL ADDED. PHOTO BY TOM MEHARG

FIG 12. SUNLIGHT ENTERING THE SOUTERRAIN FROM THE ENTRANCE. PHOTO BY AIDAN O'SULLIVAN

FIG 13. CHECKING THE HUMIDITY SENSOR BY CANDLE LIGHT IN THE CHAMBER OF THE SOUTERRAIN. PHOTO BY ROB SANDS

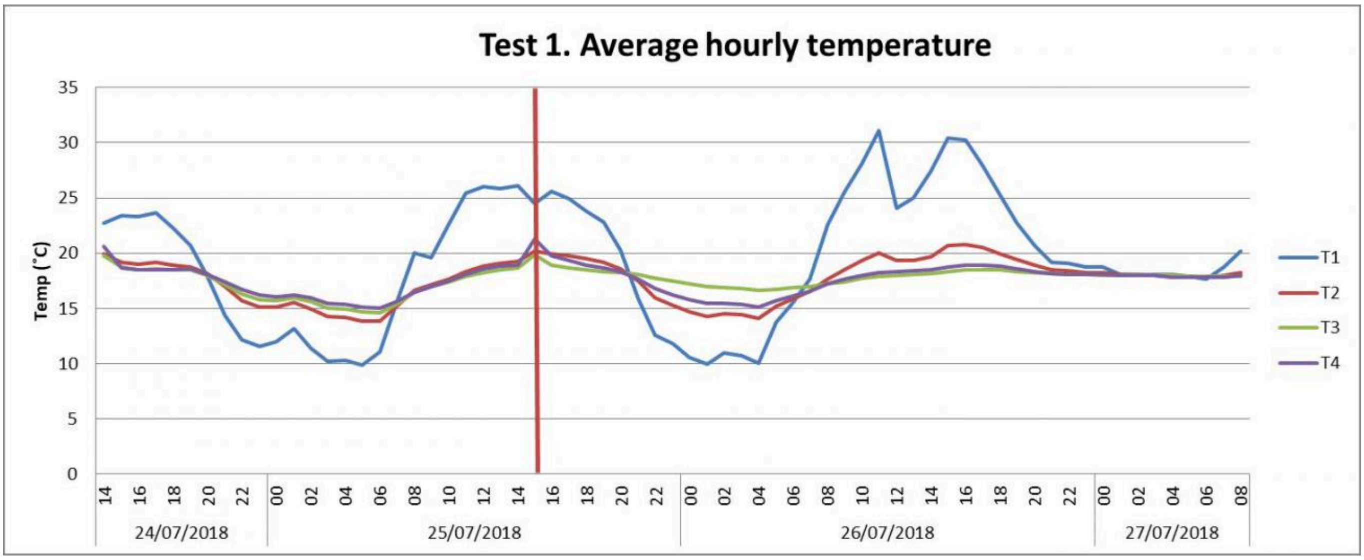

CHART 1. AVERAGE HOURLY TEMPERATURE OF TEST 1: THIS CHART SHOWS THE TEMPERATURES RECORDED WITH THE FOUR THERMOCOUPLES (T1, T2, T3, AND T4), FOR LOCATION REFERENCE SEE FIG. 2. NOTE: THE PEAK OBSERVED AT ROUGHLY 15:00 ON 25/07/2018 (INDICATED BY RED LINE) IS A RESULT OF PEOPLE ENTERING THE SOUTERRAIN.

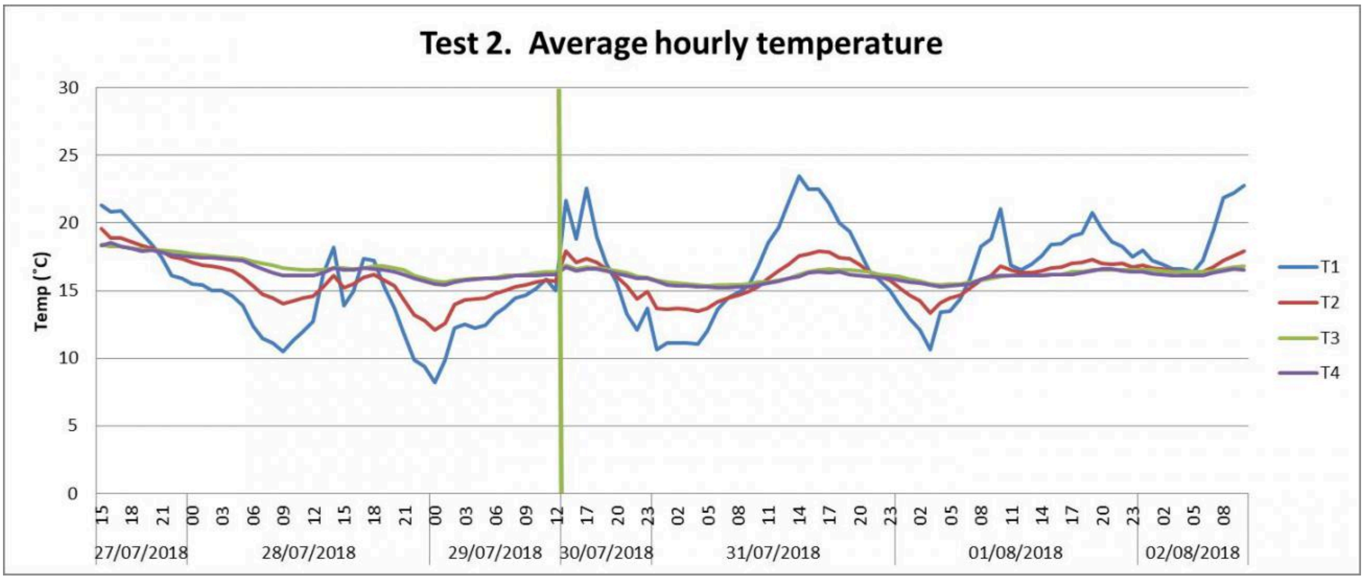

CHART 2. AVERAGE HOURLY TEMPERATURE OF TEST 2: THIS TEST SHOWS A STABILISATION OF TEMPERATURES IN THE CHAMBER (T4). AT THE ENTRANCE OF THE CHAMBER (T2) THE TEMPERATURES STILL RISE AND FALL FOLLOWING EXTERNAL WEATHER PATTERNS. NOTE: A GREEN LINE INDICATES THE PERIOD OF LOST DATA WHEN THE DATA LOGGER BATTERY FAILED.

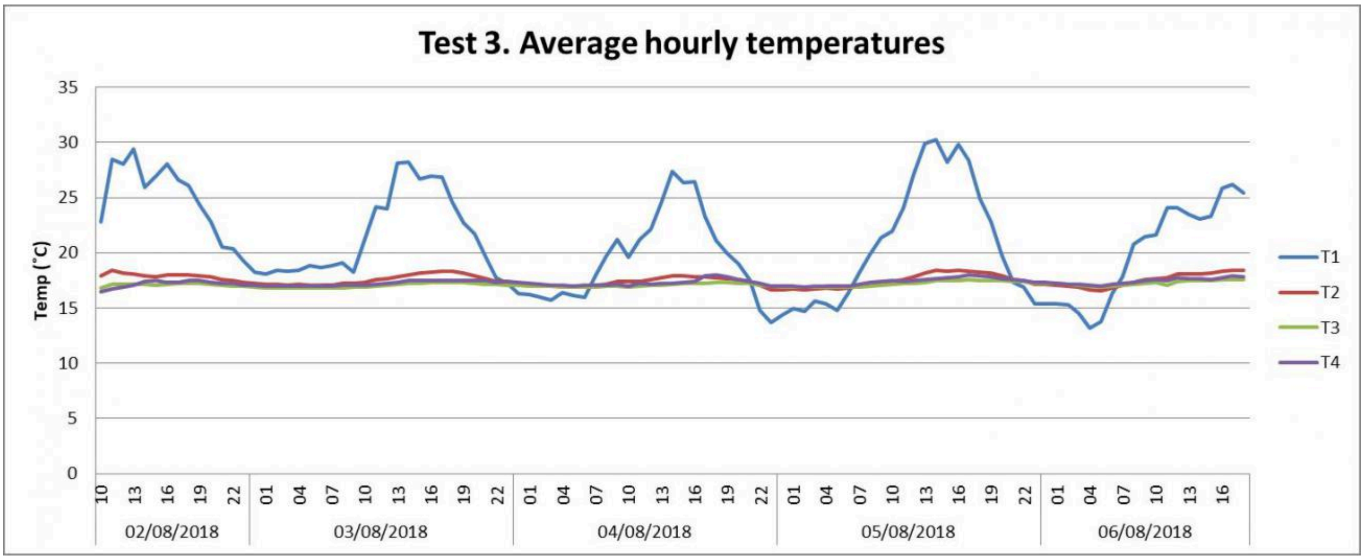

CHART 3. AVERAGE HOURLY TEMPERATURES OF TEST 3: THE MOST SIGNIFICANT PATTERN OBSERVED IS THE STABILISATION OF T2 IN THE ENTRANCE PASSAGE. THE ADDITIONAL DOOR AT THE ENTRANCE DOES NOT IMPACT THE TEMPERATURES RECORDED IN THE CHAMBER OF THE SOUTERRAIN.

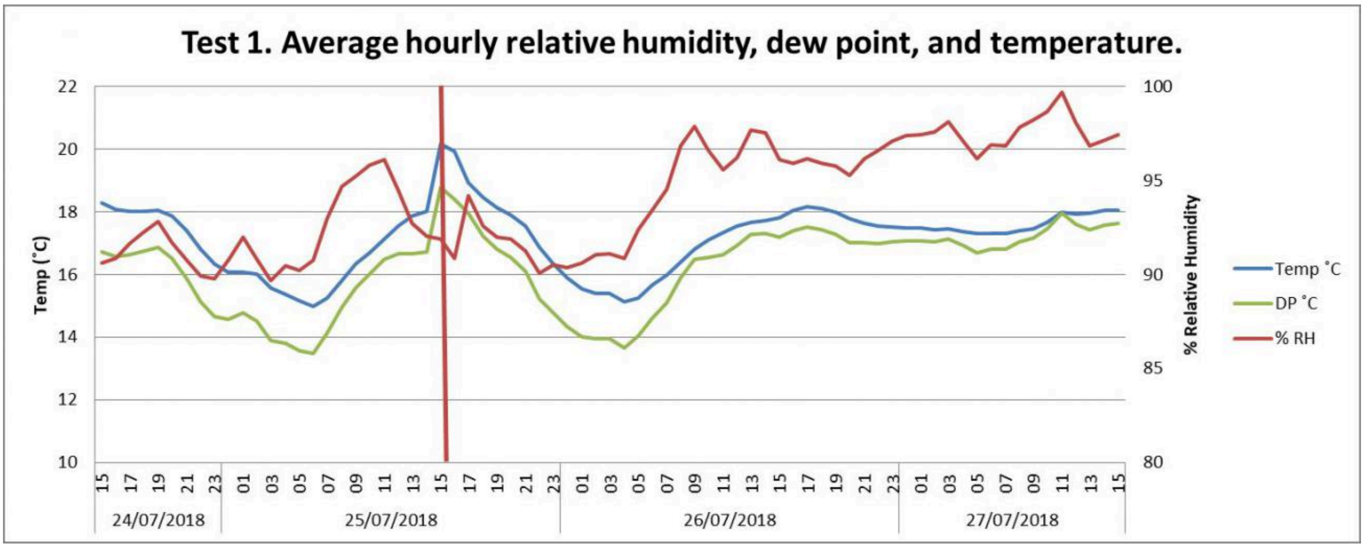

CHART 4. AVERAGE HOURLY RELATIVE HUMIDITY, DEW POINT, AND TEMPERATURE OF TEST 1: THIS GRAPH SHOWS THE RELATIVE HUMIDITY (%RH) DEW POINT (DP) AND TEMPERATURE (TEMP) RECORDED IN THE CHAMBER. THE TEMPERATURE TYPICALLY REMAINS ABOVE THE DEW POINT MEANING THERE IS NO CONDENSATION OCCURRING IN THE SOUTERRAIN. THE HIGH RELATIVE FLUCTUATES CONSIDERABLY DURING THIS TEST REACHING AS LOW AS 90%. NOTE: THE DROP IN RELATIVE HUMIDITY AND RISE IN TEMPERATURE AT THE POINT MARKED WITH A RED LINE IS WHEN PEOPLE ENTERED THE SOUTERRAIN AND THIS MOMENT CAN BE SEEN IN FIG. 13.

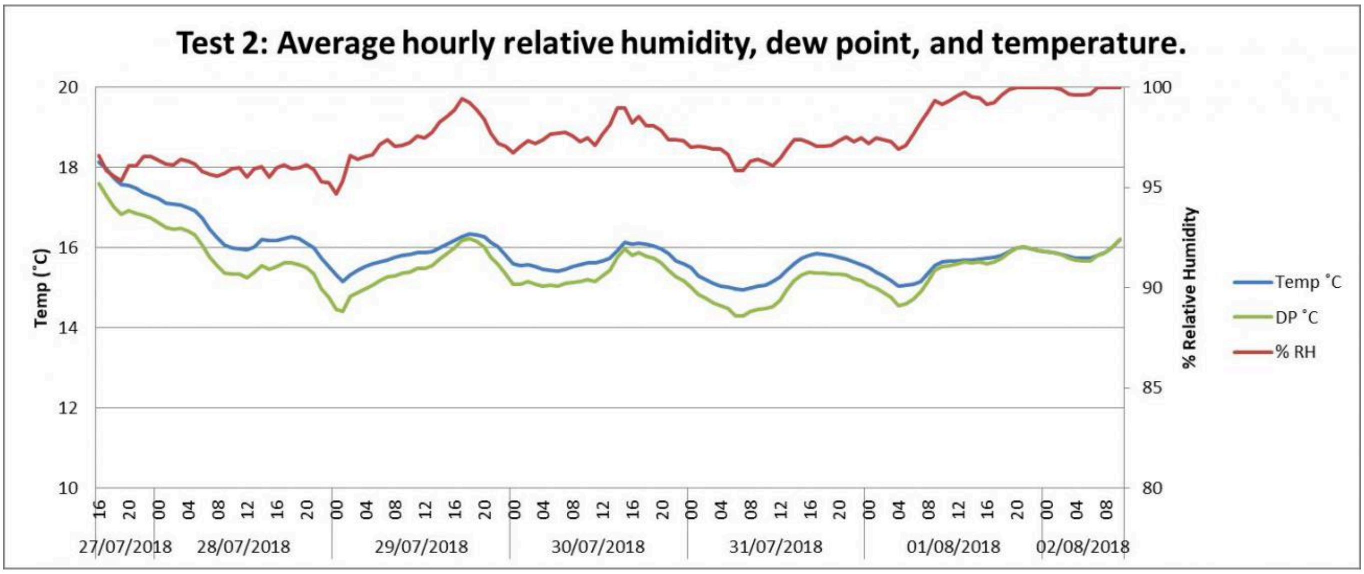

CHART 5. AVERAGE HOURLY RELATIVE HUMIDITY, DEW POINT, AND TEMPERATURE OF TEST 2: THIS PERIOD WITH A DOOR AT THE CHAMBER PASSAGE JUNCTION SHOWS A STABILISATION IN THE RELATIVE HUMIDITY AND A GENERAL TREND OF THE TEMPERATURE BEING HIGHER THAN THE DEW POINT. TYPICALLY THERE WAS NO RISK OF CONDENSATION DURING THIS PHASE.

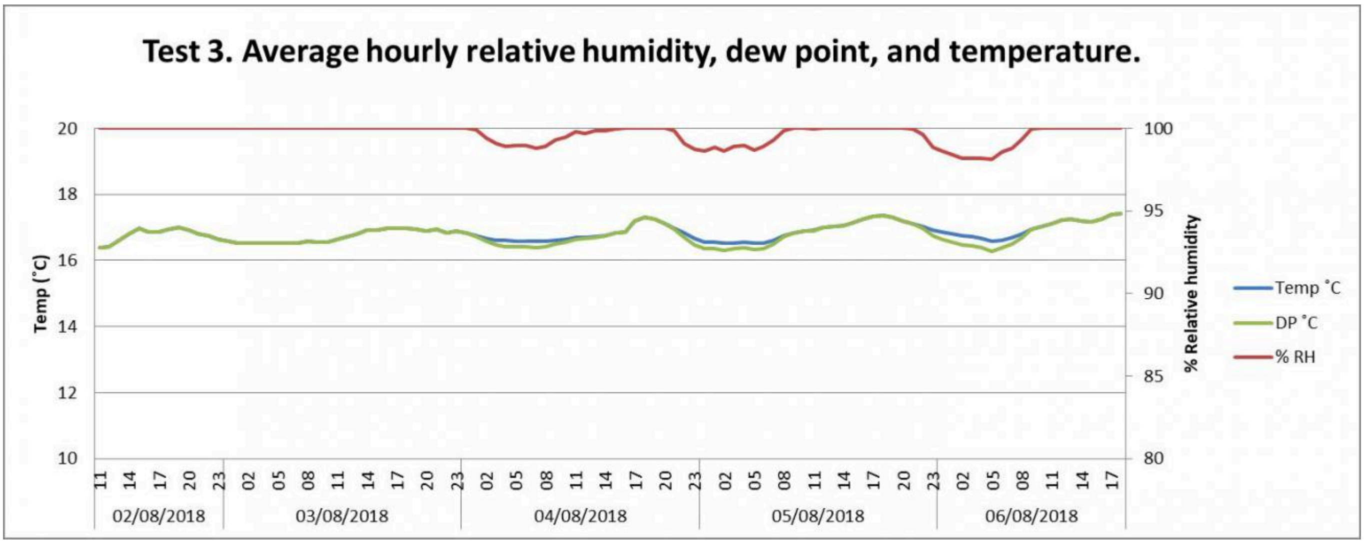

CHART 6. AVERAGE HOURLY RELATIVE HUMIDITY, DEW POINT, AND TEMPERATURE OF TEST 3: DURING THIS TEST WITH A DOOR AT BOTH THE CHAMBER AND AT THE SOUTERRAIN ENTRANCE THE RELATIVE HUMIDITY REMAINED HIGH VERY HIGH REACHING MAXIMUM SATURATION FOR CONSIDERABLE PERIODS OF THE TEST. WITH THIS AIR MOISTURE THE TEMPERATURE AND DEW POINT WERE MATCHED MEANING CONDENSATION WOULD BE AN ISSUE IN THE CHAMBER. THIS WAS LIKELY A RESULT OF A REDUCTION OF AIR FLOW THROUGH THE SOUTERRAIN AND THE LACK OF A RENEWAL OF FRESH AIR.