Age of Langcliffe Drystone Walls

The purpose of this paper is to make a case for continuing the work begun by Mike Slater (MJS) and Tom Lord (TCL) in the 2010s or so towards the dating of old dry limestone field walls, by the relatively simple process of measuring their wiggling lengths (see photo below) and comparing with the straight-line lengths. I would have pursued the work myself, but age has been taking its toll I am no longer mobile enough

MJS and TCL (plus helpers) measured a large number of limestone walls in the Langcliffe area near Stainforth and Settle and found a relation between the age of 19 of them (as derived from documentary sources) and the way their wiggly courses deviated from a straight line. MJS presented these results to the Ingleborough Archaeology Group in December 2014, which intrigued me because I had wondered why the limestone walls in the Dales wiggled compared with the walls built of igneous or sedimentary rock in the Lake District where I grew up, where they did not wiggle. The link to MJS/TCL's paper entitled "The mathematical characterization and dating of old dry limestone field walls" is as follows: - *www.northcravenheritage.org.uk/NCHT/TheLangcliffeDrystonewalls.doc*

from which this picture is taken: -

FIGURE 10 Over Pasture/South House wall looking east towards Pen-y-ghent

They had found 19 examples where there is documentary evidence for the age of the wall which showed a good linear relation between wiggliness and age, allowing them to derive equation 2 on page 8 "A = 29 w (σ_y – 4) +/- 46 years for 68% confidence limits". (A = age; σ_y = standard deviation of displacement values y; w is constant in this case.) This relation enabled MJS to make estimates of age for walls where no documentary evidence for date of construction had been found.

MJS kindly provided me with the detailed measurements of the walls' displacements from straight, and after exploring a wide range of possibilities I found that it was simply the increasing length of a wall as the years went by that was responsible for the association MJS/TCL had found.

The method used by MJS/TCL (their paper gives details, page 5 and Appendix 2 p.16) was to take successive 25m sections of wall and to measure at 1m intervals the displacement of the wall (y) from a straight line parallel to the two ends of the section. The number of sections measured for each wall varied, depending partly on the difficulty of access.

MJS/TCL in their paper did not consider the actual wiggling lengths of the walls (that is, taking into account the meanderings), but I realized that that could be calculated from the measurements that had been taken. Each one metre step gives a right-angled triangle where the displacement is one side adjoining the right angle, the step length another, and the third

(unmeasured) side, the hypotenuse (the actual length of that bit of the wall), is given by Pythagoras.

These calculations allowed the relationship between increase in length and age to be plotted, and the results for 16 of the dated walls are summarized in the attached spreadsheet file. (The excluded 3 were all given the same date, that of an Enclosure Act, but I doubted whether it was realistic for them all to have been constructed in the same year suggesting to me that the evidence needed reconsidering. Excluding them does not change the slope of the relationship, but does increase the spread.)

Time had gone by before my investigations had reached this point, and MJS had become tied up with other matters and did not wish to go any further with the work. But with the realization that increase in length was the key factor, it was clear to me that the study could be pursued much more easily than by using MJS/TCL's original procedure of measuring the displacements, because wall length can be measured directly simply by stepping a tape along the top of a wall (*e.g.* at one-metre intervals over a 25m tape length following MJS/TCL's practice) and then pulling the tape taut to record the straight-line length. The difference between those two measurements divided by the latter gives the value of dL – change in length per metre - for that particular wall section

There is a simple explanation for why a limestone wall should increase in length with age. As the wall heats up in the warmer parts of the year it will expand (the coefficient of expansion of limestone and indeed of many other types of stone and building materials is around 8×10^{-6}, that is 8 micrometres per metre of wall per C°). If the wall be constructed tightly, as is usually the case, something will have to give so the wall will buckle by a tiny extent. When cooler weather returns, the wall will contract and correspondingly tiny interstices will open between the stones. Over time, rainwater trickling down will dissolve limestone as calcium bicarbonate and redeposit it as calcite, narrowing the interstices, much as happens with the formation of flowstone, stalactites or stalagmites except that in the walls case where opposite surfaces are in close proximity there is an enhanced tendency for a dissolved substance to crystallize out. In consequence when the wall warms up again and expands, there will be insufficient slack to take up the whole expansion and the wall will buckle further.

From the age/dL relationship shewn in the attached spreadsheet, the increase in length per metre (dL) per annum is 17 micrometres (only about double the coefficient of expansion, showing that the interstices cannot be completely cemented up as the temperature ranges summer to winter are obviously more than 2 or so degrees). Accordingly, to provide some scale to the expansion effect, an 100-year old wall would have expanded by some $17 \times 10^{-6} \times 100$ metres per metre length, or $17 \times 10^{-6} \times 100 \times 25$ per 25 metre section, which amounts to 42.5 millimetres.

The stones of the Lake District walls are not dissolved by rainwater to any extent, and although a newly built wall will buckle to a very small extent when it first heats up and then open up tiny interstices when it cools, thereafter they will not be blocked by mineral deposition and will remain open to provide sufficient slack to accommodate further expansion/contraction cycles. Accordingly, there will be no tendency for the wall to buckle further.

If this work is now carried on, as I am advocating, the robustness of the age/dL relationship currently obtained will be tested, further documentary dates are likely to be found to add to the existing set, and if all goes well, depending on evaluation in the field, a new tool for investigating landscape history will be established. The only equipment needed is a good pair of legs and a measuring tape of at least 25m in length.