The origin of Maltese cart-ruts: cut by wheels or tools?

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Introduction

The origin and means of formation of the cart-ruts of Malta have been matters of debate for almost a century. The principal contenders for rut formation have been wheeled vehicles, sleds, slide cars and cutting with hand tools. Most recent authors have discounted both sleds and slide cars. The former, to be of sufficient magnitude, would create unmanageable amounts of friction, whilst there is neither archaeological nor historical evidence for the latter. The most recent publications on this topic have advocated wheeled vehicles[1] or hand cutting.[2] The former combine field observation of rut form with geotechnical information on rock strength, and conclude that the passage of wheels of, for instance, a two-wheeled cart, would create more than sufficient stress on the rock beneath to cause erosion of the local rock. The latter makes the assertion that 'there is clear evidence of ancient tool marks',[3] and concludes that cutting by hand played a significant part in rut formation. This conclusion is illustrated by two photographs of field sites showing small-scale rock surface morphologies which are interpreted as ancient tooling marks. The current paper questions such an interpretation, and whether the conclusions derived from it can be sustained by the evidence provided.

The Maltese cart-ruts are formed in limestone, a water-soluble rock. Limestone varies greatly in texture and in its content of biotic and non-calcareous components. Rutted terrains in Malta are found on the Upper Coralline limestone, Lower Coralline limestone and Globigerina limestone formations, embracing rocks of differing character which illustrate some of the variety found within this broad rock type. At the core of the current issue is the nature of the surface micromorphology of these varied rocks and its accurate identification, whether created by natural subaerial erosion processes or whether human-induced. It is also germane to consider the effects of the exposure of any such newly formed surfaces to subsequent centuries of natural weathering and erosion. In this context great care (and a geomorphological eye) is required in interpreting such minor relief forms, particularly as artefacts of human activity.

There is a substantial lexicon of small scale forms, of a few millimetres in relief, on limestone surfaces exposed to weathering. This includes features of greater or lesser geometric regularity, well documented in standard texts such as Ford & Williams[4] and Trudgill.[5] In addition to such well codified forms, there also exist forms of rather less regularity. On near-vertical surfaces such as rut walls, these include contiguous quasi-circular hollows separated by cuspate ridges, and internal solutional voids within the rock now exposed by erosion. Weathering of closely jointed rock may preferentially expose the planar faces of bedding or transverse joints. At more random level, internal variations in rock fabric, degree of cementation or biotic components may be expressed on an exposed surface as relief forms created by differential weathering.

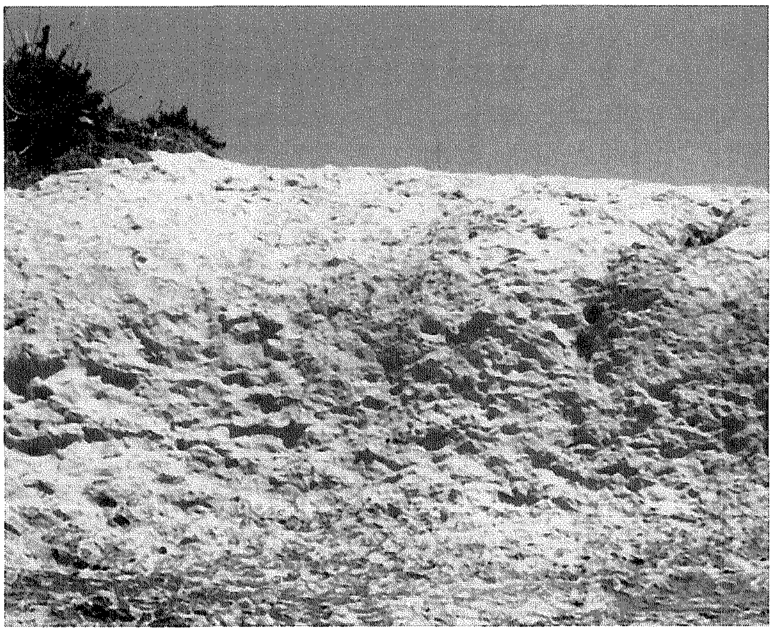

Plate 1. An ancient quarry surface at Dwejra, Gozo, showing small angular planar facets interpreted as masons' marks by Magro Conti and Saliba (2007, Fig. 59).

The Field Evidence

The evidence presented by Magro Conti and Saliba consists of two medium range photographs showing the morphology of rock surfaces, one an ancient (sic) quarry near Dwejra, Gozo, cut in Globigerina limestone, the other the sidewall of a cart-rut incised into Upper Coralline limestone at Misraħ Għar il-Kbir, Malta.

The Dwejra site (Plate 1) appears to show a bedrock slope of 40-70°, which in a high contrast image reveals a number of planar micromorphological elements, in the form of angular facets approximately vertical in orientation.[6] There also appears to be a significant number of quasi horizontal slope elements, with markedly angular junctions between the various planar facets. No scale is given, but they appear to be of the order of a small number of centimetres in vertical extent, with lateral dimensions up to maybe 15 cm in several cases. It is implied that this morphology represents marks created by a chisel or the blade of masons' picks.

There is, however, a plausible alternative explanation. These planar forms, with sharp angular boundaries, are also suggestive of joint planes, lines of fracture within the rock which have been preferentially exposed by surface weathering and erosion through the action of natural processes. Globigerina limestone is a rock of high porosity 32-41%[7] and consequent very low shearing strength of 2.20-3.85 MPa[8] and it is here directly exposed on a moderately steep slope. Directly exposed to solar radiation, it consequently experiences large and rapid temperature changes (far higher than the diurnal air temperature range), and also the deposition of damaging marine salts at high concentration in a near-coastal environment. Surface rock at this site is also directly exposed to the impact of falling raindrops, which directly apply a shearing force that increases rapidly on slopes of 45° and above. This hostile weathering environment promotes dissolution of the soluble limestone, particularly at grain boundaries, and creates mechanical stresses at these weak points by slaking (wetting/drying cycles), expansion/contraction cycles, thermal shock and salt crystallisation. Disaggregation of the rock will ensue as raindrop impact forcibly detaches loosely adherent grains and particles of rock. A soluble rock of low mechanical strength in such a weathering environment is therefore highly vulnerable to weathering (breakdown) and erosion (removal of debris). These processes would be most effective within and adjacent to existing planes of weakness within the rock, such as joints. Under these circumstances rock breakdown would initially be concentrated locally around the joints, which would in turn become exposed as planar facets as weathered material is removed, to create the type of surface micromorphologies apparent in the illustration.

Rates of weathering and erosion on Globigerina limestone can be inferred from exposed rock surfaces of known age, such as historic structures. Cavities formed by weathering and erosion on bastions in Valletta, for example, commonly show 20 mm of erosion over a period of 450 years. Applying such a rate to an 'ancient' quarry which, if related to the cart-ruts, may well be over 2000 years old, suggests that up to 100 mm of surface rock may well have been eroded over such a timescale from the site illustrated. If this is the case, then it is extremely unlikely than any original masons' marks remain on this particular rock over such a timescale; if any had existed they would by now have been obliterated by weathering and erosion. In

Plate 2. Oblique view of a rut sidewall showing curved parallel grooves, convex upwards, interpreted as masons' tooling marks by Magro Conti and Saliba (2007, Fig. 47). The field notebook rests on the lichen covered rock surface into which the rut is vertically incised.

contrast, however, if they are natural features the relatively fresh forms now apparent would be under constant recreation, refreshed by continuing erosion.

The evidence presented from Misraħ Għar il-Kbir presents a different kind of problem.[9] It comprises a sub-parallel set of curved flutes, of apparently very low relief, formed on the surface of a cart-rut wall in Upper Coralline limestone. The flutes appear to be approximately 10 mm in width and ~100 mm in length (Plate 2).

Their longitudinally curved form is convex upwards and steepening downwards. They are described categorically as 'hand cut tool marks'.[10] It is not stated what tool might have been employed or how such a tool may have been applied. The most likely tool at this scale would appear to have been a chisel-headed pick, rotating across the rock surface and etching a curved groove laterally into the rut wall. The interpretational problem created by these forms is that the axis of rotation of any tool would have been substantially below the original rock surface (Fig.1A); in other words, the rut could not have been cut downwards from the rock surface because the orientation of the curvature requires any tool to have been held below the surface itself. An alternative possibility is that the pick was used to excavate the rut by longitudinal extension, cutting back a terminal headwall (Fig. 1B). This case permits the pick to be held below the ground surface with the axis of rotation within the existing rut. The arc produced by the cutting action, however, would tend to undercut the headwall to create an overhang at the rut head. This would then need to be removed, the simplest way to achieve this being a vertical blow to the rock surface above the unsupported overhang. There is, however, no trace of marks suggesting the latter action.

A more likely style of attack with a tool would be from the surface downwards (Fig. 1C), which would create a vertical impact of the tool head, and tool marks which describe a circular arc initially orthogonal to the rock surface, then curving downwards towards the user. This procedure would also be the obvious way also to extend the headwall, bringing the blade downwards vertically on the surface in order to maximise the lateral tensile stress against the unsupported open headwall. This approach would make maximum use of the mass of the pick, and impose far less stress on the wrist in wielding it. To hold the tool low, lifting it above wrist height before rotating it is just not a natural or energy-efficient movement. It would appear that any energy efficient mode of tooling attack requires a vertical blow to the rock surface, which would create grooves of significantly different form to those described by Magro Conti and Saliba. It is concluded that the morphology of the grooves in Plate 2 is therefore most unlikely to have been formed by masons' tooling.

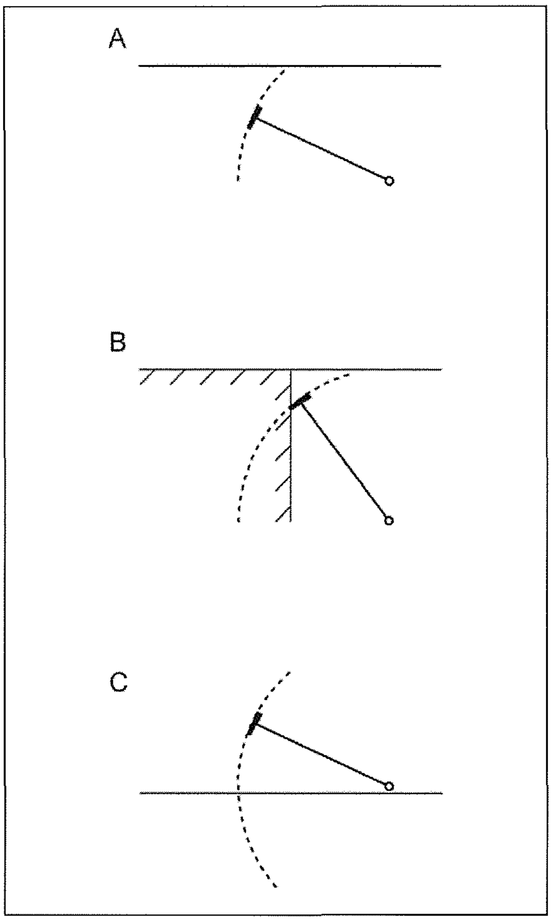

Fig. 1. Arcs of rotation caused by differing modes of attack in hand cutting a rock surface.
A) the attack required to create the groove pattern shown in Plate 2.
B) the arc formed by attacking a headcut wall with the axis of rotation required to form the groove pattern of Plate 2.
C) the groove pattern created by a normal attack on rock forming the ground surface.

A further issue is that the supposed tooling marks appear to have a length of at least 100 mm. It would appear that in order to generate sufficient momentum to form such marks, which would evidently represent a single sweep of the tool, a metallic head of significant mass would be required. No archaeological evidence of such artefacts has been presented which, given the abundance of cart-ruts across the islands, is perhaps surprising.

Furthermore, although the image is described as showing an absence of dissolution features, a number of fossil fragments appear to stand out from the rut wall surface, and an area of bas-relief in the wall appears to reveal a sediment-filled cavity. These areas of differential relief are, in fact, indicative of differential dissolution and show that weathering has indeed taken place since the formation of the rut. Although there is no obvious alternative interpretation of these fluted forms other than some material variation of unknown source within the rock fabric, the arguments presented above suggest strongly both that they were not formed by human tooling, and that significant subsequent dissolution has taken place since rut formation. Such dissolution is likely to have diminished rather than preserved any original tool marks.

Discussion

It is argued above that the evidence presented for tooling marks in relation to both ancient quarrying and cart-rut formation creates significant difficulties of interpretation. Furthermore, there are difficulties in both cases as to whether original forms supposedly created over 2000 years ago could have survived subsequent weathering and erosion.

Resolution of this contention requires an independent test of the nature of masons' marks, and of their capacity for survival over a long period of historic time. Such a test would consist of an examination of locations where the following conditions are satisfied:-

that stonemasons would have been active

there would have been no competing activities capable of creating cut surfaces, and

cut rock surfaces have been exposed since their formation.

The opportunity for such a test exists locally in the form of ancient quarries such as those at Misraħ Għar il-Kbir where grooves cut into the solid rock have been manufactured in cutting out regular ashlar blocks, and Imtaħleb, where cut quarry faces over one metre high remain exposed. If masons' marks are to exist anywhere, then they would surely be present at such quarry sites, where processes other than deliberate cutting are most unlikely to have been operative. A careful search of both sites, in glancing sunlight, of surfaces self-evidently cut by human artifice revealed no marks of the kind interpreted by Magro Conti and Saliba as tooling marks. If similar marks to those described by Magro Conti and Saliba cannot be found in such locations, where they are most likely to exist, then it can be concluded either that they were not created by masons or that any masons' tooling marks which may have been created have been destroyed by subsequent weathering and erosion. In either case it is implied that marks described by Magro Conti and Saliba have some other cause.

Recent evidence of the relationship between rut patterns and limestone rockhead relief (the form of the bedrock surface beneath an overburden cover) has led to a new model of rut formation.[11] It is reasoned that ruts were initially formed on the surface of soil material overlying a buried rock surface. Erosion of the soil by passing traffic gradually exposed the underlying bedrock, onto which the cart tracks became superimposed, incising ruts into the newly exposed rock. In this way, the ruts would be formed by linear abrasion along the lines of the wheel tracks. Patterns indicative of longitudinal abrasion along the length of the rut are shown, for example, by the ruts at Imtaħleb (Plate 3), where longitudinally persistent edges and shelves in the rut walls form consistent cross sections along the length of the ruts.

Plate 3. Cart-rut at Imtaħleb showing multiple levels in the rut walls formed by longitudinal abrasion.

Conclusion

The evidence presented by Magro Conti & Saliba in support of hand tooling, to this author at least, appears less than conclusive. In the light of careful consideration of small scale forms on limestone surfaces, and of natural weathering and erosion processes, it is contended that rather stronger evidence would need to be presented before an unequivocal interpretation of human action can safely be made. This would include consideration of the clarity, detail, frequency and distribution of the forms supposedly created by human handiwork. The case would be strengthened by independent evidence of their origin, and also a consideration of the likely style of tool usage. It is particularly the nature of geomorphological features, where similar forms may represent the end point of more than one process, that there is danger in inferring process from form without independent supporting evidence.

A broader perspective on rut formation can be taken by considering the rut network as a whole. Summing up the currently extant ruts presented in the gazetteer of Magro Conti and Saliba[12] suggests that c. 35 km of ruts remain. The rut planform sketches provided make it clear that those that remain are merely fragments of much more extensive patterns, whose original length is clearly a substantial multiple of the remaining network fragments. It would appear inherently unlikely that any significant fraction of the original whole was cut by hand, given the resources of human labour and tools that that would demand.

Acknowledgements
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Notes

1 D. Mottershead, A. Pearson and M. Schaefer, 'A geotechnical approach to the formation of the 'cart ruts' of Malta', *Stone* 2 (2007), 5-6.
D. Mottershead, P. Farres and A. Pearson, 'The influence of environmental change in the formation of the 'cart ruts' at Naxxar', *Stone* 2 (2007), 7-8.
D. Mottershead, A. Pearson and M. Schaefer, 'The cart-ruts of Malta: an applied geomorphology approach', *Antiquity* 82 (2008), 1065-1079.

2 Magro Conti, J. & Saliba, P.C. (eds.), *The Significance of Cart-ruts in Ancient Landscapes*, (Malta. Midsea Books, 2007).

3 Ibid., 69.

4 D.C. Ford and P. Williams, *Karst Geomorphology and Hydrology*, (London. Unwin Hyman, 1989).

5 S.T. Trudgill, *Limestone Geomorphology,* (London. Longman, 1985)

6 Magro Conti and Saliba, fig. 59.

7 J. Cassar, 'Deterioration of the Globigerina Limestone of the Maltese Islands', in S. Siegesmund, T. Weiss and A.Vollbrecht (eds.), *Natural Stone, Weathering Phenomena, Conservation Studies and Case Studies*, (Geological Society of London Special Publication 205, 2002), 33-49.

8 J. Saliba, *The shear strength of Globigerina Limestone*. B.E.&A.(Hons.) unpublished dissertation, University of Malta, (1990).

9 Magro Conti and Saliba, fig. 47.

10 Ibid., 57.

11 D. Mottershead et al. (2007), and D. Mottershead, P. Farres and A. Pearson, 'The changing Maltese soil environment: evidence from the ancient cart-tracks at San Pawl tat-Tarġa, Naxxar', in B.J. Smith, M. Gomez-Heras, H.A. Viles and J. Cassar (eds.), *Limestone in the Built Environment: Present Day Challenges for the Preservation of the Past*. (Geological Society of London Special Publication 331, 2010).

12 Magro Conti and Saliba. 193-287 in Appendix I. Gazetteer of cart-ruts in the Maltese Islands.