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Reverse engineering and the archaeology of flowing materials. A response to Gabriel Moshenska's paper

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First of all, thanks to Gabriel Moshenska for raising such interesting questions regarding the relationship between reverse engineering and archaeology. His paper does an excellent job in setting out similarities and alignments between the two sets of practices, opening up the topic for further discussion. The author takes us a certain distance along a path of comparison, equips us with some well-honed ideas to carry with us, and then leaves it up to us to make of them what we will, or take them in whatever direction we choose. In picking up the challenge thus laid down, I will argue that archaeologists do indeed reverse engineer after a fashion, and that this not only has important implications for our understanding of archaeological inference: more than that, reverse engineering has potential to be of practical use to archaeologists in their investigation of specific types of material evidence, which I will go on to discuss.

Reverse engineering might at first seem to be most applicable to artefacts or machines, sometimes quite complex ones like the Antikythera Mechanism or Vulcan bombers. This leads Moshenska to consider the relevance of reverse engineering mainly with regard to industrial artefacts in a post-industrial age. But as he rightly points out, such things can be so complex, their maintenance and operation so bound up with tacit expertise and embodied rationales, that there are practical limits to what reverse engineering can realistically achieve.

Of all the examples given by the author, however, the one that strikes a chord for me is Pettigrew's unravelling of the Egyptian mummies. The mummies in question are neither mere artefact nor machine. Nor are they of modern date. In unrolling the layers of bandages and flesh, Pettigrew acquires insights which inform his own embalming practices. He unwraps the body of the ancient other in order to acquire the necessary bodily expertise, so he can then physically wrap the bodies of contemporary others with appropriate skill. He does not have access to the tacit knowledge of ancient Egyptian embalmers, but through engagement with their handiwork he learns much about materials used, techniques deployed, and intentions put into practice.

What Pettigrew does in unraveling Egyptian mummies, it seems to me, is essentially what archaeologists do in their archaeological investigation of sites and landscapes. It is not so much artefacts or complex mechanical devices that archaeologists reverse engineer, however – nor bodies for that matter - but sequences of strata. The landscape is seen to be layered, with later accretions / truncations above or cutting into earlier ones. We excavate layers in opposite order to that in which they were laid down – latest first, earliest last, so that the processes through which they have accumulated can be understood. This is broadly akin to Messler's account of reverse engineering as 'taking apart to learn'. The object of reverse engineering, then, does not have to be a technological artefact in the narrowest sense of the term: we can include sites and landscapes as well as portable tools and machines in that description.

Of course there is an art to fieldwork and the archaeologist acquires his or her own layers of embodied expertise, so to speak, in the process of investigating sites. To unravel a site is to do much more than seek to understand the physical traces of past human actions / intentions. There are biological and geomorphological forces to take into account too, and the physical traces of these are intermeshed with those of human forces in complicated ways that are hard to disentangle. But this does not render the comparison between archaeological fieldwork and reverse engineering unviable. Far from it - it actually makes the comparison more appropriate.

Reverse engineering has always been about physical engagement with materials, taking things apart with the hands as well as the mind, as much to do with the interaction between humans and other material flows and forces as about abstract reasoning alone. That is what is intriguing about it. It cuts through dualisms inherent in much discussion on forms of scientific inference, and moves us beyond polarities of mind and matter, ideas and things, practice and theory. The sheer physicality of dismantling an engine and putting it back together, or unraveling the bandages of an Egyptian mummy, is significant. Reverse engineering is a practical and physical process as well as a mental one. It is a wrestle with materials as well as with ideas, even if it overtly accords primacy to the latter by its over-emphasis on the importance of the original design.

Moshenska defines reverse engineering as 'the process of reasoning backwards from a technological artefact to the initial problem or design specification it was created to solve or fulfil'. But we are already beginning to take that definition apart, dismantling its main components one by one, so we can put it together again in a slightly different way, broadening it out in the process.

We should make clear for example that by 'reasoning' we are referring to *practical* reasoning as well as to *analytical* reasoning. Not all reasoning takes place solely in the brain, but is somehow distributed throughout action fields where hands and brain are used in unison, in deployment of appropriate tools of the trade on problematic materials. In postulating the existence of an initial preconceived 'design', we should entertain the alternative possibility that there could have been no original plan as such. Past human agents and artisans must often have proceeded by flexible and creative processes of trial and error, learning from the materials that they were engaging with, developing ideas in response to practical problems encountered, working out designs as they went along (Ingold 2013).

Matter is not just a passive recipient of the force of human intentional agency, and does not always submit compliantly to the constraints of preconceived designs. Materials being assembled or disassembled have a quality of vibrancy and liveliness (Bennett 2010) which disrupts even the best laid plans, and should therefore be considered as active participants in the political ecology of manufacture and design. With this in mind, it becomes clear that what one is working back in reverse engineering may be an interactive process rather than a plan - or ideational-material engagements rather than conceptual entities alone.

There is a good reason why I have sought to broaden out the concept of reverse engineering beyond its original specifications. I see it as being especially applicable and relevant to one particular field of research in which I have a longstanding interest, and that is the archaeology of flowing materials. Here we are necessarily talking about landscapes (or flowscapes) as much as about technological artefacts, and how these have been shaped in part by human beings alongside other material agencies. Working out the techniques and rationales employed by people in the past – attempting to reconstruct something of the content of their former expertise - has real relevance for future policy and practices. Yet in many cases all that survives for inferences to be based on are the derelict structures themselves – ditches, channels, levees, sluices, weirs, dams, staunches, drains, leats, qanats, terrace walls, etc - in their landscape setting and stratigraphic context.

Reverse engineering is applicable here because of certain basic realities that both people in the past and archaeologists in the present must respect. One is the fundamental principal that water and other flowing materials are subject to the force of gravity and tend to flow downhill (other things being equal). This provides a useful baseline around which deductions can be made, and in terms of which reverse engineering questions can be framed. We might ask, for example, how past peoples have made use of or modified landscape topography in order to harness or resist the energy of gravity-driven flows, and what were they trying to achieve in doing so?

Such questions can be addressed archaeologically. Let us suppose for instance that beneath a Neolithic house a series of interconnecting drains are discovered during the excavation of the site. An obvious technique to use would be to survey and map the drain system, recording heights along the floor of each drain. The resulting plan would show the gradient or slope of the drains and thus the direction of flow, revealing which drains flowed into which, where the water was channeled from and where it was channeled to, which drains were bringing flow into the house and which were taking it away, and so on. Since the drainage system in this case did not arise naturally but was a skilled accomplishment, involving integrated expertise in thought and practice, something can be usefully said about the intentions of the makers of the drain system.

Similar techniques can be used on much larger scales. The Anglo-Saxon town of Wallingford is surrounded by impressive enclosing defensive rampart and ditch, known to have held flowing water. To try and understand how this water management system worked, levels were taken along the floor of the ditch to ascertain gradient and therefore the direction of flow. Such data facilitates not just a description of the physical form of the monument, but also something about the intentions of the Saxon hydraulic engineers (for that is effectively what they were) who constructed it. any map showing direction of flow is also a map of their enacted intentions, modified in practice to take account of the many material challenges the local topography must have presented (Edgeworth 2011: 88-91).

A third example of where reverse engineering can usefully be deployed is provided by the various kinds of terracing which are to be found over large areas of terrestrial surfaces of the Earth, especially in the Far East. Terraces support the production of food on a vast scale. Such structures modify local hydrology and prevent erosion. Indeed, it seems that in many cases the intention behind them (to use a loaded term) is to make use of the gravity-driven flow of materials precisely by resisting it, trapping the downward moving water-borne sediments behind the terrace walls to create fields of fertile soil. Yet many of these terraced fields are of ancient origin, and knowledge of the techniques of construction has been lost in many cases. Reconstructing such knowledge from archaeological investigation of the stratigraphy of terraces, by means of a kind of reverse engineering (which takes account of the material as well as the conceptual forces at work), could be of immense value in informing future policies of soil conservation and sustainable agriculture.

In short, as a field archaeologist with an interest in the archaeology of flowing materials, I find the concept of reverse engineering both problematic and inspiring. It has archaeological potential. Of course it is important to be critical of aspects of it, and to adjust its methods to suit archaeological purposes. But one thing is for sure. The next time I carry out a project on the archaeology of rivers or water management, it will be in part an experiment in archaeology as reverse engineering.

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