Research Article

Paul Reilly*, Ian Dawson

Track and Trace, and Other Collaborative Art/Archaeology Bubbles in the Phygital Pandemic

Abstract: This paper describes our creative responses to a surface assemblage (a scatter) of lithic artefacts encountered on either side of a worn track across a field early on in the pandemic. Our art/archaeology response takes place within a phygital nexus in which artefacts or assemblages can be instantiated either physically or digitally, or both. In the nexus we create, connect and explore an ontological multiplicity of – more or less – physical and digital skeuomorphs and other more standard forms of records for sharing (i.e. Latour's immutable mobiles, such as photographs), but rendered with radically different properties and affordances, at different scales, with different apparatus. These include interactive Reflectance Transformation Images, graphical surface models, machine intelligence style transfer, and 3D prints, all of which were produced in a variety of isolated analytical "bubble" settings and transmitted to and from (both digitally and physically) a home office in an isolated Hampshire village and a home studio in a London suburb. Our approach is to describe, diffractively, the ontological shifts and itineraries associated with some of these objects and assess how this assemblage came to matter as an art/archaeology installation. Ultimately, some of these deterritorialised, (re)colourised, affective, biodegradable, and diffractively born metamorphic instars, now inscribed with new meanings, are returned to the original findspot of the lithics to be (re)discovered.

Keywords: 3D printing, art/archaeology, cognitive assemblages, diffraction, phygital

1 Introduction

In 1967, the later to be famous sculptor Richard Long hitch-hiked from his home in Bristol to his art school at St. Martins. In between hitches, he decided to retrace his steps repeatedly backwards and forwards until he had flattened the grass into a transient line across a field in Wiltshire. Before he left, he photographed his work (Renfrew, 2003, pp. 35, 36). A "gelatin silver print on paper and graphite on board" fixed this intervention within the "art object" now preserved in the Tate collections (Burgon, 2012). History doesn't record what Long was looking at as he tracked to and fro across that particular field tracing his line. Had any archaeologists happened across Long's ephemeral sculpture in the landscape, they would probably have paused to consider what it was and question how it came to be there, who made it, and for how long

* **Corresponding author: Paul Reilly,** Faculty of Arts and Humanities, University of Southampton, Avenue Campus, Highfield Southampton, SO17 1BF, United Kingdom, e-mail: p.reilly@soton.ac.uk
Ian Dawson: Winchester School of Art, University of Southampton, Park Ave, Winchester, SO23 8DL, United Kingdom, e-mail: i.dawson@soton.ac.uk

Figure 1: A line made by walking in Hampshire.

had it existed? Equally likely, they would have examined the ground on either side of the line to determine if the track had been cleared, like the Nazca lines, or indeed Long's later works, such as *A Line in Bolivia* (Renfrew, 2003, p. 32), or whether it was unintentional and just a by-product of the action of walkers. Actually, when Paul Reilly encountered a very similar line crossing a comparable field just over the county border in Hampshire in 2020, that was precisely what he did. Like Long, he also took a photograph (Figure 1).

Since the crop (corn/maize) in the field was still very sparse, and the world that day was paralysed by the COVID-19 pandemic, Reilly having few other distractions took the time to look very closely at everything along and either side of this beaten track. A distinctive banana-shaped stone caught his attention. Leaning down for a closer look, he encountered a beautiful knapped flint object whose form corresponded to what archaeologists would typically characterise as a mesolithic period "pick."

By chance, this encounter happened on the weekday on which aficionados of the Lithic Society often share tweets using the hashtag #FlintFriday. Friday mornings were also the regular slot for the authors and two other archaeological and fine art colleagues to meet up, virtually, and progress a volume on trans-disciplinary *Diffractive Images* we were co-editing (Dawson, Jones, Minkin, & Reilly, forthcoming). During our wide ranging discussions, we had already touched upon how lithic artefacts were presented in art. For example, the left-hand panel of the *Melun Diptych*, by French court painter Jean Fouquet (c.1452), depicts *Etienne Chevalier with St. Stephen* with oils painted on oak in the Northern Renaissance style. The patron saint is bearing what looks distinctly like a patinated flint core (Dawson & Minkin, 2019, pp. 234–235). Inspired by this early juxtaposition of art and archaeology, the present authors agreed to develop this encounter in the cornfield and further explore, diffractively, the materiality and temporality of this parti-cular assemblage as an *art/archaeology* collaborative project. Art/archaeology, as conceived by Doug Bailey (Bailey, 2014, 2017a, 2017b), aims to *disarticulate, repurpose, and disrupt* "artefacts from their pasts and to release them into the contested dynamics of the present, through the making of new creative works, not traditionally seen as historic or archaeological in form, display or intention" (Bailey, 2017b, p. 700). Importantly, "[r]ather than producing institutionally safe narratives conventionally certified as truth, archaeologists should follow the lead of artists who use the past as a source of materials to be reconfigured in new ways to help people see in new ways" (ibid, p. 691). Here we include archaeologists trying "to

challenge their own practice-based research *creatively*" (Thomas et al., 2017, p. 121 original emphasis) or, put another way, those applying their creative imagination (e.g. Gheorghiu & Barth, 2019; Gheorghiu, 2020). Our challenge would be to overcome the impact of the pandemic and turn it into a positive stimulus to generate creative new art/archaeology assemblages, practices, and insights.

2 Pandemic Problems in a Phygital Nexus

When the 2020 Coronavirus lockdowns hit, like everyone else, our everyday lives and work activities were dislocated dramatically. "Track and Trace," besides being an allusion to the trodden path across the field, is a term that can be applied to the category of programmes aimed at testing for contagions and the subsequent contact tracing operations to quarantine potentially infectious individuals or clusters. In the UK, "bubbles" were introduced to strictly limit social contact and help reduce transmission of the coronavirus. Defined categories of people (e.g. single parent families, senior citizens, and special needs individuals) were permitted to "bubble up" in small, tightly defined, social groups to alleviate the effects of lengthy social isolation. The impact of social distancing policies for most of the population was profound and lengthy. Social isolation did not simply entail remote working for more than a year, it also suspended access to key equipment housed in our departments; apparatus that we normally relied on to help progress our transdisciplinary art/archaeology research project exploring the affordances of something previously described as a *phygital nexus* (Gant & Reilly, 2018). Phygital is a neologism which refers to an increasingly apparent universe in which *phy*sical and di*gital* artefacts intersect one another, holding out the promise of substantive new ways to (re) consider the materiality and ontology of objects (Ingold, 2012). We conceive of this nexus "as a no-place and an everyplace in which the boundaries between what is physical and what is virtual are blurred, where digitally defined objects. are susceptible to transmutations and may be (re) deposited within multiple parallel or intersecting physical and digital assemblages (e.g. Reinhard, 2019), and are able to "jump" almost anywhere in our digitally hyper-connected universe. In addition, phygital objects can be invoked, instantiated and brought into constellation with other practices and entities both physical and virtual, and "messy" [ontological] assemblages can, and do, emerge from these interventions. Phygital transformations, moreover, may be multi-directional: digital objects can become physical and, conversely, material instantiations can be virtualised (Dawson & Reilly, 2019). In short, assemblages in the phygital nexus are not only physically, digitally, spatially, and temporally itinerant, they are also ontologically itinerant as objects mutate and glitch in accelerated transformations as they move through physical, digital, and hybrid realms (Opitz, 2019; Reilly, 2015b).

    To continue our long running collaboration (Callery, Dawson & Reilly, forthcoming; Dawson & Reilly, 2019) under the severe restrictions imposed to curtail the pandemic required us to discover expedient substitutes for key elements of apparatus no longer at hand and then develop novel remote collaboration workflows across our depleted phygital nexus. The most productively problematic aspect of this project was that only Reilly had "met" and maintained direct physical contact with the lithic assemblage at the core of this project. Initially, Dawson could only watch and listen to Reilly handling, gesturing, and describing the artefacts via Microsoft *Team* sessions. To enable meaningful collaborative work on this lithic assemblage, it first had to be ingested into our phygital nexus so that we could share and develop our practice-based insights and *phygital acts of discovery*. We pick up on Matt Edgeworth's insight that in the shift from fieldwork to screenwork it "is clear that a general rethinking of archaeological discovery is necessary, taking due account of computers and the Internet as intrinsic elements of the mixture of human and nonhuman flows, forces and materials that together make up contemporary archaeological assemblages and encounters" (Edgeworth, 2014, p. 51) and extend it into our art/archaeology phygital nexus. Within this nexus, we adopt an "agential realist" perspective, and our point of departure is Karen Barad's (2007, p. 210) key insight: "Matter is substance in its intra-active becoming – not a thing, but a doing, a congealing of agency. Matter is a stabilizing and destabilizing process of iterative intra-activity."

    To be clear at the outset, our project does not attempt to offer any kind of autoethnography or reflect on our working practices through the critical filters of Science and Technology Studies (STS). While such

approaches clearly have merit, we consciously try to eschew fixing our outputs as translations (Lucas, 2012; Olsen, Shanks, Webmoor, & Witmore, 2012) into immutable mobiles (Latour, 1987), which might stabilise our practices in standardised hinterlands of method assemblages (Law, 2004), or the values embedded in the socio-technological infrastructures (e.g. Bowker & Star, 1999) associated with our phygital nexus. We certainly acknowledge that our approach has parallels to Suchman's (2012) trope of (re)configuration. However, our focus, intent, and approach are fundamentally different. In this art/archaeology paper, we are not taking congealed socio-technical relations and reenacting them differently, we are actively disarticulating and *diffracting* our archaeological and artistic practices and images, subsuming our quotidian methods, techniques, tools, and apparatus, and rearticulating and repurposing them as *art/archaeology*-imbued stepping stones to enable us to step, as it were, outside the bubble of our own and our apparatus's cognitive faculties. Where these stepping stones lead is not yet clear. They are, however, significant points of departure. Perhaps, we should be more apprehensive. Regardless, the notion of a bubble allows us to apprehend a scene from both inside and outside, and to look away (Derrida, 1993), thus bursting the boundaries of what can be apprehended. Bubbles of various kinds emerge throughout this paper because we see in them much generative potential. Be they physical, digital, phygital, social, disciplinary, theoretical, technological, metaphorical, or allegorical, bubbles can separate and isolate, as well as bound and interface between things, all at the same time. Bubbles can also exist inside other bubbles. They can be beautifully parametric, or fascinatingly irregular. They can also be light and flexible, hard and durable, transparent, translucent, or opaque. They exist in both inorganic and organic realms. Eggs and cocoons are particularly inspiring examples of nascent bubbles of becoming. Cocoons are special kinds of bubbles, being places for both refuge, regeneration, and *metamorphosis*, that is safe environments for spontaneous and amazing transformation (Ingold, 2020). Bubbles are also diffractive objects and a form of lens. Our approach is to describe, diffractively, our subversive transdisciplinary experiments within, and through, our bubbles of creative digital practice and the consequent ontological shifts and itineraries associated with our lithic objects, and then assess how this extended assemblage came to matter as an art/archaeology installation.

Despite an impaired and imperfect phygital nexus, artefacts or assemblages can still be instantiated either physically or digitally, or both, radically transformed. Indeed, phygital objects can be changed back and forth from one materiality to many potential others. Within our nexus, we create, connect, and explore an ontological multiplicity of – more or less – physical and digital skeuomorphs and other more, but generally less, standard forms of records for sharing such as photographs, at different scales, with different apparatus. These include interactive 360° spherical panoramas, 3D Structure from Motion (SfM) graphical surface models, Reflectance Transformation Images (RTIs), and 3D prints which were produced in, and transmitted to and from (both digitally and physically), a home office in an isolated Hampshire village and a home studio in a London suburb.

3 Phygital Acts of Discovery and (Dis)location

Returning to the initial "act of discovery" (see Edgeworth, 2003), the flint artefact by the path crossing that chalkland field was photographed in situ. An interesting moment of diffraction began to unfold around the geometry and material (silica) of the glass lens of the camera, which is both perfectly symmetrical and materially an amorphous solid and the isomorphic cryptocrystalline lithic, which is scarred and asymmetrical, in their chalk and corn setting. Reilly made a 360° panoramic mosaic of overlapping photographs using Google's *Street View* app to produce an interactive spherical panoramic photograph. Unlike a conventional photograph, which locks the subject within the tight constraints of the enfolding rectilinear frame, the spherical panorama enables the cyborg viewer to look both "inwards" at the lithic subject, but also "outwards," situating the artefact in the context of a wider landscape. Land, sky, and artefact are digitally meshed together. Strangely, as in traditional archaeological photography (inter alia, Bohrer, 2011; Conlon, 1973; McFadyen & Hicks, 2019; Morgan, 2016; Shanks, 1997; Shanks & Svabo, 2013), in this form of "bubble vision" (Steyerl, 2018) the photographer has been dislocated and anonymised, an absence

Figure 2: Unwrapped 360° panoramic photo of a flint tool encounter in a Hampshire field.

presence in the centre of this empty orb. That aside, this spherical panorama provides more spatial context about the findspot than a conventional photograph, and the interactive viewer in *Street View* affords users semi-autonomous capabilities of rotation, pan, and zoom around these digitally painted bubbles. But like all interactive media exploration, it is limited not only by the sophistication of the technology, but also by the functional literacy of the would-be explorer using it (e.g. Smith, Beale, & Opitz, forthcoming). Visitors who find themselves disembodied in the middle of this spinning spherical panorama are still securely locked down in a particular spot within a very thin slice of time, in limbo, that was initially determined and framed by Reilly, who thereby inadvertently created another set of "social bubble" restrictions in the context of the pandemic.

The unwrapped and flattened compilation of the spherical photogrammetry shown in Figure 2 is suitable for 2D printing, but is at best only a halfway house between the interactive 360° panorama and a conventional flat photograph. The "view" is much more constrained as the viewers' ability to explore it is reduced to panning across, and zooming into, the warped image.

3.1 A Material Incursion

After being digitally dislocated, Reilly once again reengaged physically with the material artefacts there in the cornfield. After millennia of the combined elemental effects of earth, water, wind, and fire, this pick still persisted and had developed a wonderfully lustrous amber-like patina. Form and substance afford different perceptions of an artefact. This object when picked up had none of the warmth and lightness of amber that a

Figure 3: Mesolithic "pick," 140 mm × 65 mm, 300 g, flint (Anonymous, c. 10000–4000 BCE).

superficial haptic gaze might suggest, nor did it offer any olfactory hint of resin. At the first touch it felt hard, cold, and dense. The only smell belonged to the soil that still clung on. Proprioceptors in the hand, wrist, forearm, and elbow pushed to the fore of perception as ocular impressions were recalibrated. This asymmetric, weighty, but well-balanced, lithic artefact "fitted" perfectly into the grasp of Reilly's right hand. More material qualities asserted themselves: the remaining pitted cortex *feels* to be deliberately left in place to provide slightly rough textured gripping pads for fingertip and thumb holds. None of the hard, sharp, and potentially slippery elements need make contact with the grasping hand (Figure 3). When the artefact was measured, it was 140 mm long by 65 mm wide and weighed 300 g. It has a lot more presence than simple bald statements of facts can convey.

Walking to and fro along the path that Friday led to several other lithic objects conventionally dating back to somewhere in the mesolithic period (c.10000–4000 BCE). It soon became apparent that although they are all made from flint nodules and exhibit much in common stylistically, no two are the same. Each member of this scatter assemblage presents a unique, materially specific narrative of making which has been determined as much by the affordances of the materials of the nodules and hammer stones as the hands of the makers. No obvious indications of how any of these lithics came to be scattered across this field are discernable. Unstratified, and adrift in time, their relative order of coming to this place is indeterminate, but there, basking in the sun, they had become contemporaries and to some extent co-located. As mobile network coverage in this part of the world is patchy and unreliable, this spread of lithics was loosely pinned down using the *what3words* location platform. Eerily, the W3W application seems to have noted the crop and assigned a very apt triplet for one group of neighbouring lithics (i.e. https://w3w.co/overruns. cornfield.send).

The next step was to enable and extend the assemblage for collaboration. This involved, initially, washing the lithics and then subjecting each artefact to two standard but complimentary archaeological computer photography practices, both in a somewhat ad hoc manner: Reflectance Transformation Imaging (RTI) and photogrammetric SfM. As with the *Street View* 360° photo spheres, both these techniques rely on the creation of virtual photographic bubbles to enframe the subject. Here too, the hands and eyes of the photographer are hidden behind the lens, and like any other photographic technique, digital or analogue, they carry with them "genealogies of practices of looking and recording" (Jones & Díaz-Guardamino, 2019, p. 211) that are "neither neutral nor objective" (Cochrane, 2018, p. 182) and are applied deliberately for a

purpose. They are "volatile images" (Beale, 2018) being deliberately articulated and repurposed; in this case, in such a way as to facilitate the exploration of novel aspects of the materiality and temporality of this assemblage. Once again, viewers are given semi-autonomous capabilities to interact with the digital artefacts.

Several forms of RTI are commonly used by archaeologists, artists, and curators in museums and galleries, namely dome-, highlight-, multispectral-, micro-, and underwater- RTI (inter alia Back Danielsson & Jones, 2020; Clarricoates & Kotoula, 2019; Earl, Martinez, & Malzbender, 2010; Historic England, 2018; Jones & Díaz-Guardamino, 2019; Malzbender, Gelb, & Wolters, 2001; Mudge et al., 2005; Selmo et al., 2017). They all share in common a basic studio format in which both the camera and the subject are held rigid and multiple photographs are taken, each one with the light source in a different position, but equidistant from the subject; in other words, underneath a virtual hemisphere of lights.

In this half-bubble, the artefacts are completely disconnected and de-territorialised from the contexts from which they originally emerged, and then rearticulated, retemporalised, and fixed within a controlled, synthetic, negative space illuminated by flickering lights that produce meaning-making highlights and shadows. The arrangement is very similar to that described in Plato's allegory of the cave (c.375 BCE) in which he describes prisoners having their heads fixed so that they see only the shadows deliberately cast on the cave wall by the gaolers in order to manipulate their (mis)perception of some external reality. In both cases, the viewpoint is crucial for drawing meaning from what is being revealed (see also Jones, 2020, p. 90). In the case of RTI, however, the flickering lights and shadows are synthesised to produce a digital skeuomorph, using an extremely precise description of the subject's geometry, which can be interactively relit, and its surface properties manipulated. These facilities can dramatically enhance the viewer's perception of the object they are trying to get to know better and perhaps collaborate with, as opposed to creating dystopian illusions. Perhaps Plato might have approved.

With access to institutional imaging equipment impossible, an improvised highlight RTI (H-RTI) rig was put together using equipment and substitutes available to hand: the tripod for the camera is a plant stand with wire supports tied on; the strobe was replaced by a bicycle lamp; the vital reflective sphere, or bubble, without which the subject's geometry cannot be extracted, was a christmas tree bauble; the camera was set up to take 50 photographs at 2 s intervals.

Makeshift H-RTI shoots were performed in a nighttime darkened home office (Figure 4). The images were then ingested into the *RTI Builder* which is available free from Cultural Heritage Imaging (http://culturalheritageimaging.org/Technologies/RTI/) and compiled using the highlight-based PTM (polynomial texture map) fitter option. In practice, this means that the reflective bubble in the images is located by the user, then the software takes over and automatically detects the position of the bubble's highlights for every
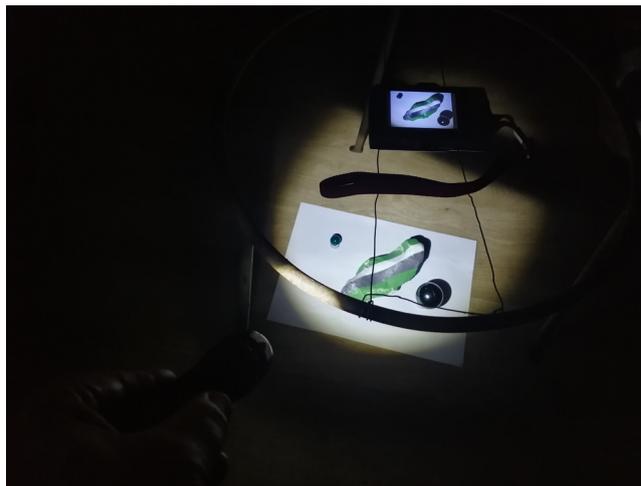

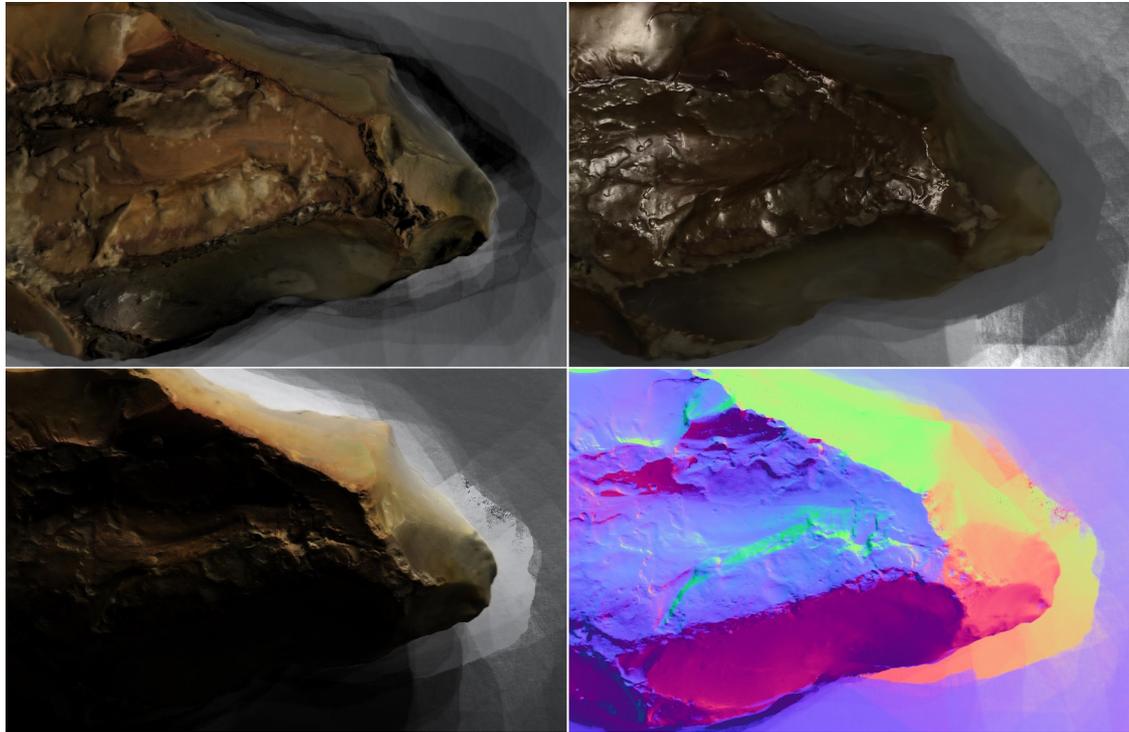**Figure 4:** Nighttime shoot with improvised H-RTI rig.

Figure 5: Example render modes of same part of pick.

image. The lighting information from all these images is then synthesised into a mathematical model of the subject's shape and colour properties which are encoded in such a way that each constituent pixel displaying the compiled RTI will accurately model how light behaves at the specific point of the surface it is depicting. Users of the *RTI Viewer* software can interactively re-light, zoom-in, and pan across their models and analyse it, albeit from a fixed viewpoint, in extremely intimate detail. Researchers are also endowed with superficial alchemical powers of transmutation. The material properties of the object's surface can be transformed at the drop of a menu because this application also has adjustable "rendering modes" which enable users to change the displayed surface properties instantaneously to be, for example, more diffuse or more specular (e.g. Figure 5). Some types of marks which would normally be missed, unnoticed by the naked eye on, for example, a bland, rough stone surface can leap out when that speck of geometry they occupy is rendered chiaroscuro-like as a smooth metallic material, enlarged, and dynamically lit from many oblique angles. These functions radically enhance the capabilities of the researcher who, for instance, could unpick much more easily and efficiently the operational sequence of each blow that shaped this artefact's becoming. Eyebrows were raised when RTI analysis of the Folkton drums, already well-known to research, revealed evidence for previously unrecorded motifs, erasure, and reworking. These objects were shown to be palimpsests and not decorated according to a single, preordained scheme, but were successively carved and recarved over time (Jones et al., 2015; Minkin, 2017).

Artist Simon Hitchens has developed a contrasting approach of intraacting with portable lithic objects, light, time, duration, shadows, his pen, and the marks they all engender. He ignores all visual surface details of the silica rock (chert) he is studying and instead records the subtleties of its three-dimensional form using its imprint on time. He does this by tracing the fluid outline of the shadow of the rock due to sunlight as it drifts and morphs at intervals from sunrise to sunset (e.g. Hitchens, 2015). In the finished work, the footprint of the rock in the landscape emerges as a blank silhouette enmeshed by the superimposed, orderly, and penned progression of "shadow lines." The results are surprising, beautiful, and coherent; time, temporal order and duration have been harnessed to help create a new understanding of the rock. In the *RTI Viewer*, however, time does not obey the rules of linear temporal order. Indeed, both may

Figure 6: Temporal diffraction pattern and mesolithic pick in H-RTI frame.

become plastic and pliable and, if handled in certain ways, turn brittle and friable, and time's bubble will burst.

Consider the static frame from a compiled H-RTI of our mesolithic pick using the default settings in the RTI Viewer interface shown in Figure 6. Notice the fringe of interlaced shadows surrounding our lithic subject. This is an example of what physicists call a diffraction or interference pattern. Specifically, it is a temporal diffraction pattern in which "different times bleed through one another" (see Barad, 2017, p. 68). It is created by peaks and troughs of waves of light and shadow overlapping and either reinforcing (brightening or darkening) or cancelling out one another. Light, darkness, and time seem to travel hand in hand. We normally experience these waves of light in linear flows such as those laid out in Hitchen's haunting meditations on duration and transience. In the *RTI Viewer*, however, the ribbon of time has been unpicked, cut into fragments, and can be shaken up like the particles in a snow globe. How can that be, given that the skeuomorphic green bubble provides apparently smooth navigation around the subject? Click the cursor on any point on this bubble and the world is refreshed to show what the subject looked like when the light source was pointed at it from that direction. Skim the cursor across the navigation bubble in any direction and the lighting on the subject is dynamically adjusted to match those lighting points, causing the shadows and highlights to swirl and slide around as this particular hand ballet unfolds. Time, however, is stumbling about this space, hopping to and fro. Its once well-beaten track has become an erratic dotted line, a quantum ellipsis of superpositions.

4 SfM Photogrammetry Bubble

The RTIs were created as the lunar bubble waxed and waned. Photogrammetry followed in the daylight hours in another makeshift studio, this time in the garden to obtain the best lighting conditions. Each artefact was fixed in place to the top of a conveniently high step ladder using bluetack and photographed in the round (i.e. yet another bubble scene of overlapping images). As with the RTI project, these images were shared via the internet in order that Dawson might get a better handle on the assemblage and respond to it creatively. His first response was to process the photogrammetry using Agisoft *Metashape* software and build interactive SfM 3D models (e.g. Figure 7).
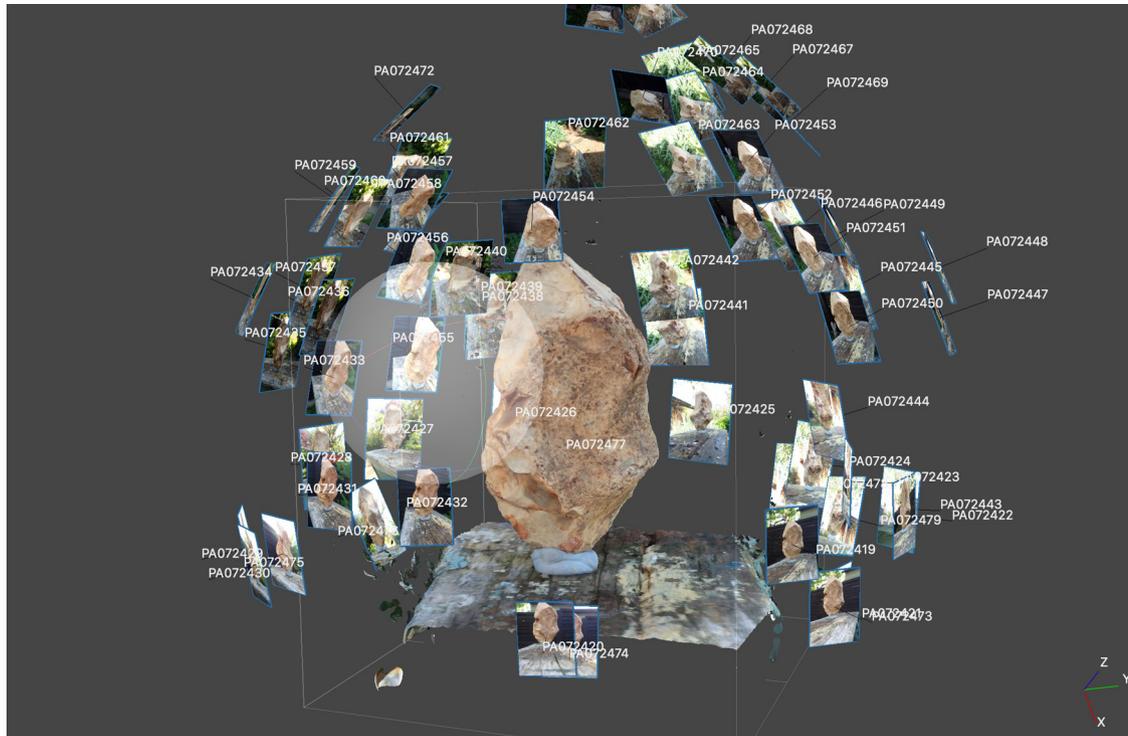
Figure 7: Screenshot of SfM Mesh bubble with axes.

He outputs stereolithographic (STL) files to create experimental 3D prints which are colourful and challenging material reconceptions derived from the digital artefacts and reinscribed with new latent meanings arising from practices of renewal, transformation, and repurposing. The printer refixing fractured moments in its unrelenting linear oozing of duration.

5 Isolated in the Pandemic: Track and Trace

"Bubbles," "isolation," and "track and trace" are three prominent features of the pandemic landscape. A handful of key factors tie these features together, namely location, setting, time, and duration. These very same factors are central to our collaborative explorations of the lithic scatter. How things come together and interact in particular space and time, and for how long, matters. The application of RTI (Historic England, 2018) and the SfM photogrammetry (Historic England, 2017) gave us important insights into the multivalent temporality of the scatter assemblage, the topology of the individual objects, and their superficial materiality.

While Dawson was building out and exploring the plasticity of SfM photogrammetry in plastics, Reilly was fascinated by the temporal diffraction patterns revealed by the RTIs. In parallel, he was increasingly interested in the diffractive possibilities of the popular computer vision technique of image "style transfer" which relies on sophisticated "neural algorithms of artistic style" (Gatys, Ecker, & Bethge, 2016) using a very deep convolved neural network (Simonyan & Zisserman, 2015) to extract the style of one image and transfer it onto the content of another (for a full treatment on style transfer see Miller, 2019, chapters 7–12). In other words, it produces another form of diffractive image that interlaces different styles and different subjects through a machinic way of seeing (e.g. Graham, 2019).

We began to explore how different times, materials, and places could be diffracted through this assemblage, and one another, using this technique. Our point of departure was the mesolithic pick we introduced at the beginning of this paper (Figures 3–6). Our "content image" is a frame from our compiled RTI, in

Figure 8: #FlintFriday – Silica Alchemy IV, 2020.

which the fringe of normally unremarked upon interlaced shadows is also a temporal diffraction pattern. The first material property we wanted to diffract with the RTI of the flint and its accompanying diffraction artefacts was stained glass. Inspired by Dawson's flamboyant 3D-printed confections (see below), an image of a colourful stained glass panel was used to define the style.

One outcome of this experiment is *#FlintFriday – Silica Alchemy IV* (Figure 8), which is quite a departure from standard, but nevertheless very sophisticated, representations of lithic objects (e.g. Lord, 1993 Raczynski-Henk, 2017; van Gijn, 2010). This is one of a series of diffractive digital studies exploring the recursive intra-action of light, shadows, silica, and (artificial)neurons (Reilly, 2020). In this study, the archaeologist's analytical gaze upon the impact scars that shaped the flint tool is radically interrupted

Figure 9: *Trace and Trace I*, 2020 (Diffractive Image – style transfer QR w3w location code and flint RTI).

Figure 10: *Track & Trace II*, 2020 (Diffractive Image – style transfer location setting satellite landscape image and detailed flint RTI).

midway through the process of capturing its RTI portrait, and then subject to the machinic gaze of the *style transfer* deep neural network, before being rendered as another kind of diffractive image in which the RTI multi-lit flint artefact and its compound shadows are seemingly transmuted into backlit stained glass (Figure 8).

The QR-code has become a zeitgeist of the pandemic, capturing as it does those key factors of ontology, time, location, and place. A QR code is a machine readable optical label that can describe to which it is attached. In *Track and Trace I* (Figure 9), the pick's findspot has been rendered as QR code using its unique *what3words* location triplet, which was then style transferred onto the same compiled RTI image used in *Track and Trace I* (Figure 9).

Lastly, for this set of *recursively* diffractive images, a satellite image showing the neighbourhood and setting of our lithic assemblage's findspot was interlaced with our, by now, signature RTI content image (Figure 10). What emerges looks like an island microcosm of the chalk downlands set in a shallow sea, the "pick" once again isolated, set adrift in time, and lapped by temporal ripples. This novel form of diffraction also interlaces dramatically different viewpoints of both the artefact and its setting simultaneously from a *great distance* and in *close detail*. Figure 9 and 10 are examples of what Zylinska (2017) calls "nonhuman photography" in her book of the same name. Nonhuman photographs are not *of*, *by*, or *for* humans (Zylinska, 2017, p. 5 original emphasis). This is not to say that these images are unthought or mindless artefacts, somehow artless, nor that humans have no part in their making. As Zylinska argues, all images will embody both human and nonhuman elements. Figure 9 and 10 are also examples of what Zylinska (2020, pp. 109–111) calls "undigital photographs." They display dramatic artistic changes to the original computational images made after they were originally taken by both human and artificial intelligences.

Perhaps, it was our own sense of isolation during the lockdowns, but we became acutely conscious that this archaeological assemblage had been physically separated from the landscape from which it had emerged. The 360° panoramic bubble photographs and the diffractive style transfer pieces were an attempt to bridge this rift and to place them back, if only virtually, in an appropriate place and moment of re(dis) covery. However, while these images are rich in meaning, perhaps even provocative, and may even imbue a certain sense of their place in the landscape, that landscape was now bereft of the flint scatter. We therefore wanted to physically reconnect the newly inscribed assemblage with the landscape, setting, time, and materials from which it had emerged. Our next experiments involved further (im)material diffractions with time, and then artefacts with place.

6 Diffracting Materials, Scale, Time, and Place

The initial act of discovery of these flint artefacts happened in a cornfield with a track across it, on the chalkland landscape known as the "downs," in Hampshire, UK. Chalk is the progenitor of silica, flint, chert, glass, and so also our lithics and our camera lenses. Chalk is an ostentatious medium in its own right, beloved by builders, geologists, fossil hunters, sculptors, teachers, and mathematicians. This substance calls to be (re)shaped and invites lively movement and thought. It is the didactic material, par excellence, which has encouraged the development of countless ephemeral tracks across blackboards around the world for generations. Mathematicians are particularly indebted to it. As Barany and MacKenzie (2014, p. 115) explain: "The consequences of chalk for mathematics are not just practical but ontological and epistemological [as] arguments are enacted and validated through their performative unfolding – an unfolding as absent from circulable mathematical texts as it is essential to the production and intelligibility of their arguments."

Above the chalk is our field, the corn emerges, heading straight upwards in a hurry, from the crumbley, grey, alkaline soil, pushing aside flint nodules and lithic artefacts on the surface, and is aligned in arrow-straight green dotted lines. The lines of corn form nearly orthogonal axes with the line of beaten track and the chalk bedrock below, and so now something else has to be added to our unfolding assemblage. Corn is central to Dawson's practice. It is the raw material for many of his most recent works which involve experimental 3D-printed components.

For decades, additive manufacturing has enabled fabrication using many different, and multiple combinations of, materials. However, it has only been in the last few years that 3D-printing has become popular in art and archaeology (e.g. Eve, 2018; Reilly, 2015a, 2015b). The 3D-printed works developed in Dawson's *plastic studio* are based on polylactic acid (PLA), a biodegradable polyester derived from corn starch. The base of lactic acid is produced in our bodies during exercise as carbohydrates produce it as a by-product (it's what makes your arms ache if you have been knapping flints vigorously for an extended period, and similarly your legs after a long run). The same fermentation occurs on an industrial scale with homofermentative methods of production. PLA is biocompatible with the human body. It may be implanted as biodegradable support structures inside substitute body parts. It can also be ingested orally, accompanied by a characteristic sour taste, with for example sourdough and homebrews. Externally, the cosmetics industry lathers our skin with it. Without question, PLA is an incredibly vibrant material. Dawson tries to respond intuitively to the material while working from a position of unfamiliarity, the act of discovery still the bedrock of his practice (Dawson, 2012, p. 9). In an increasingly phygital age, he has been extending his methods of creation from the physical and into the digital.

Seeking to address correspondences between materiality, imaging, digital, and physical discussions, even the material properties of plastic should be considered with their long chains of polymers. The material itself is chemically refractive. To be more precise, lactic acid has a particular optical rotation which is birefractive, meaning that a ray of light passing through it will be split into two rays with diverging paths. This is chemically possible because lactic acid has a particular geometric property it has in common with DNA and amino acids: it is a form of chiral molecule, which means that – as with several of our flint artefacts – it has an asymmetric structure that cannot be superimposed on its mirror image by any combination of rotations and translations. Like human hands, such molecules exist in stereo; related to one another by reflection. Each of its left-handed and right-handed molecules will have a single carbon molecule at its stereogenic centre (a molecular fixed point). They are almost the same, but have a different arrangement of atoms in space and are considered optically active on a chemical level. In other words, the material that feeds the 3D printer to draw thousands of superimposed images, in layers upon a print bed, to be worked and reworked within Dawson's studio, and later (re)captured through RTI, can itself be described as optically active, and like some lithic artefacts, it exhibits handedness.

Figures 11 and 12 are frames of a compiled H-RTI of a Dawson sculpture using different rendering modes. In Figure 12, strands of plastic are being explored in the same way as the worked surfaces of flint tools or chalk drums by exploiting RTI capabilities to affect light across a material surface in order to discover layers of plastics, making and meaning. These two images raise a question: what correspondences

Figure 11: RTI of PLA Assemblage.

Figure 12: Detail of PLA Assemblage RTI.

exist between gestures, materialities, and geometry and the images that emerge through their intimate encounters?

Now it was Reilly's turn to watch Dawson handling his reinterpretations of the lithic artefacts from the cornfield in his biodegradable "plastic studio." There had been issues connected with the affordances of the printers and the printing medium, in that they have to be printed in such a way as to assemble correctly and efficiently (both in terms of labour, energy, and material consumption). All of the above could be implicated in Benjamin's (1936 [1968]) famous injunction concerning "mechanical reproduction." Although these objects could have been reproduced as identical 3D-printed facsimiles, in fact, like their lithic prototypes,

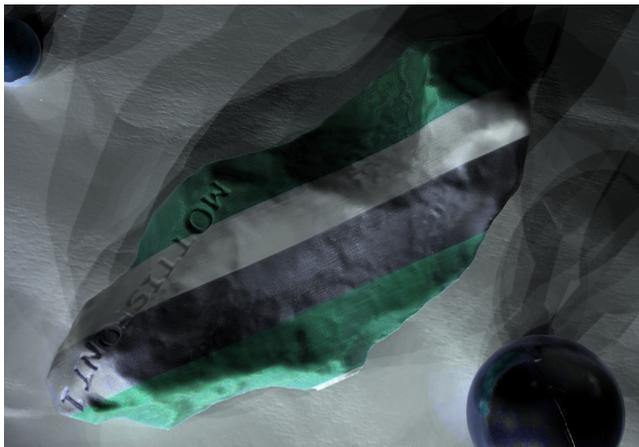**Figure 13:** Mesolithic pick with dazzle diffraction.

Figure 14: RTI of inscribed PLA pick with oblique green-, white-, and grey-dazzle.

no two are the same. An essential stochastic element is introduced by the maker spontaneously changing the colour of the filament when it is convenient or it just feels right.

Grown from a cornfield, the vibrant, regenerated artefacts that appeared phoenix-like on the screen of our e-meetings were strikingly reinscribed with new meaning. For example, the once familiar lithic topologies and textures that had been extracted so carefully from the SfM photographic surveys to enable the original chaîne opératoire to be determined now reemerged, covered in a profusion of third millennium dazzle that fundamentally redefines the visual encounter. One of the first to steal the stage with its razzmatazz had the duration of its making laid out in stunning pink, white, amber, yellow, black, and grey bands progressing along its entire length, causing the new colourful stratigraphy and the original chaîne opératoire of impact scars to diffract through one another. This particular candy rock like scheme also brought gustatory confusion of *all sorts* (Figure 13). Over a period of several weeks, every individual lithic in the assemblage was generated afresh, each with its own unique colour scheme, laid out in various orientations (e.g. Figure 14) and at more or less random scales.

Several of the PLA works were rendered multiple times at different scales and in different liveries. A colourful, cosmopolitan, and very lightweight collection was packed in a box, handed over to the Royal

Figure 15: Phygital finds tray: Interlaced corn and flint assemblage.

Mail postal service, and tracked online to Hampshire. Once "back home," our itinerant objects were introduced to their sturdy rural cousins (Figure 15). It very soon became apparent that aside from their striking gaudiness, which actually proved very complimentary to the lithics, the biggest difference between the two assemblages revolved around their weight and balance and was how they fitted (or otherwise) into the hand.

In this regard, one rather dowdy PLA artefact stood out (Figure 16). It had been printed using the same technology and processes as the rest but, uniquely, it had then been coated in chalk powder (by being turned over in a revolving bubble for several hours) that was a very close match to the colour of lithic prototype's own patina. The object that emerged from this process was uncanny. It appeared a most convincing lithic artefact, but it felt completely wrong when it was picked out of the delivery parcel. This was because although it looked like the original lithic, its weight, balance, and texture were discon-sonant with its appearance, and so it provoked repulsion, especially when it was handled with the flint

Figure 16: Uncanny pandemic object.

Figure 17: Painted pebbles in and around a Test Valley village and along its public rights of way.

prototype held in the opposite hand. Remarkably, once safely installed on a display stand at an arm's distance away, this artefact no longer feels like some kind of uncanny pandemic object.

For the rest, we planned to release them back into the wild under the cover of a diversion. As it happened, school children had over the pandemic taken to placing colourfully decorated pebbles around the village and paths where Reilly lived. A favourite type of spot to deposit these little works of art is on gate posts, the fingers of waymarkers, on stiles and, sometimes, just simply at the side of a footpath. They are also found in various nooks and crannies just off the public footpaths in the woods and fields thereabout (Figure 17). These wonderful objects can be admired and even handled, before being returned to their place of display.

Curiously, the track about which our lithic assemblage was discovered had no decorated pebbles along its course nor at the waymarkers and stiles at its start and finish. Their absence provided cover for our installation. We release our dazzling assemblage of phygitally related artefacts, unannounced, back into the field close to the places the flint lithics were first discovered by the track – the colourful worked corn substitutes replacing their patinated worked flint counterparts. They are (re)introduced when it feels right, when the corn is ripening (Figure 18), or when the corn has been harvested (Figure 19) for example.

7 Summary and Discussion

Bubbles have emerged in this project as potent vehicles for creativity in practice as well places of personal mindful refuge and intellectually positive spaces for free thinking in the time of the pandemic. They serve as both cocoons and incubators, places where metamorphosis can occur. In fact, a single lithic scatter found in

Figure 18: A dazzle in the corn crop just before harvesting.

a cornfield during the pandemic has been transformed through the dramatically different lenses of a veritable "bubblescape." Like the contemporary paintings of Jeffrey Dennis, our art/archaeology bubbles represent intense shifts in micro- and macro-focus (Read, 2017) in relation to how we examine and experience objects within both their places of discovery and their ongoing displacements in time and space.

This paper had its origin within membranes of cortex, stretched around blobs of flint, buried in the chalk floor of an ancient sea. Some of these silica bubbles eventually percolated up into a mesolithic landscape where they were encountered by tool makers who burst them open and discovered that the broken pieces could be fabricated into wonderful objects. Some of these artefacts persisted for millennia and then were (re)discovered and recognised for what they were, by their distinctive technological style, in a cornfield with a path worn across it, in the pandemic of 2020. This assemblage of lithic artefacts now became caught up in a series of new art/archaeology analytical-creative bubbles that interpenetrated one another over many dimensions, including place, setting, time, material, scale, technologies, and cognition. The first of these was the 360° spherical panorama that fixed the "act of discovery" using a mobile device and a credit card photographic scale. While this both inward and outward looking landscape bubble recorded some of the setting of the discovery, its location was also affixed to a named 3 m^2 square mapped onto W3W's meshed bubble representation of the earth. Although viewers could look around the place and setting of the act of discovery, this visual bubble has an element of claustrophobia and conveys a sense of being locked down to a particular moment of time. This led us to several other bubbles that functioned as portals allowing slightly more autonomous and, perhaps more importantly, diffractive exploration of our assemblage via an (im)materially, temporally, and technologically effervescent phygital nexus.

The RTI project invoked a kind of quantum bubble in which time and materialities were pulled out of the shadows to be diffracted through one another in order to unpick not only the chaîne opératoire of the making of an artefact, but also the operational sequence of registering each artefact in an interactive RTI
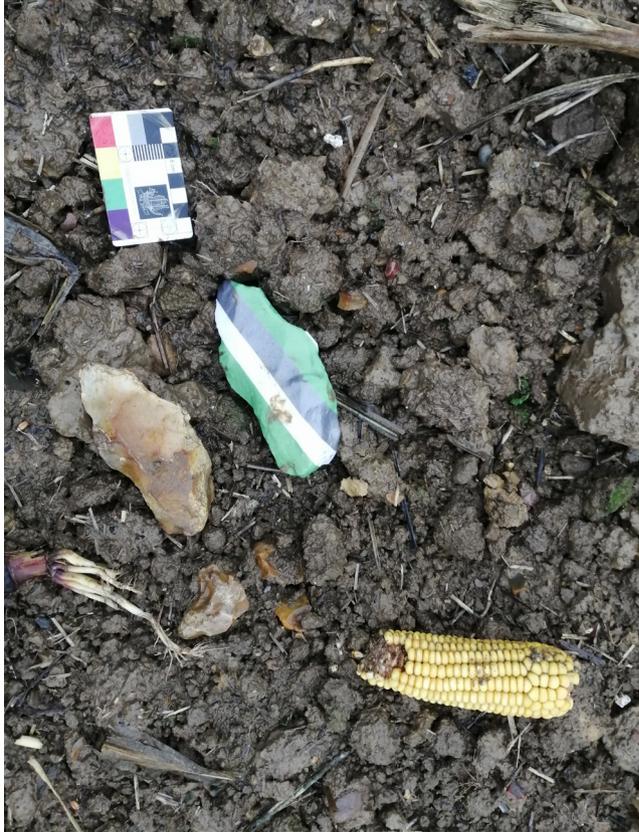
Figure 19: The cycle of silica and corn continues.

polynomial texture map. As compiled into the RTIViewer, users are able to interactively explore the making and use of these objects (i.e. the artefact and the RTI) by remixing the material surface properties and lighting sequences. However, now fixed in their RTI bubble, our artefacts had somehow come adrift both in time and place. In an effort to return them, creatively, to their silica origins and setting, compiled RTI images encapsulating the temporal diffraction patterns in their making were, in turn, diffracted, using a style transfer algorithm in a cluster of artificial neural bubbles, with meaningful style images: stained glass panel; a QR location code; and a satellite rendering of their find spot. In parallel, a SfM bubble provided a medium to connect Dawson in his plastic studio in London to the geometries and surface details of each individual artefact from the lithic assemblage.

All the art/archaeology artefacts from the 360°, SfM and RTI computer photogrammetry, and image style transfer fall into the category of "simulacra." First described extensively in the work *On the Nature of Things* written by the poet and philosopher Titus Lucretius Carus around 50 BCE, simulacra (called "idols") have the appearance of things from the real world, but are actually just empty films or membranes which have been shed off the real body of the thing they came from, like a snake's skin (see also Minkin, 2016; Lucretius, 2020). They may be considered as empty bubbles without organs. Therefore, feeling that the artefacts in our virtual assemblage had been "deprived of their matter" (Stobiecka, 2019), we decided to (re) materialise the assemblage in such a way as to recall the place, vibrant matter, and form of the original lithic assemblage but with a contemporary art/archaeology twist. The silica artefacts were therefore 3D-printed at very different scales, in dazzling colours, using biodegradable, corn-based, PLA, to create extreme skeuomorphs. The dazzle liveries radically disrupt the visual encounter while indicating the duration of their (re)making as they are diffracted across the traces of the impact scars and chips that shaped the making of the lithics. When touched, the comparative warmth and lightness of the decorated "plastic flints" is a startling contrast to the cold hardness of their silica forebears.

The analytical bubbles we have outlined above share a number of common human and nonhuman elements. Each one includes a group of artefacts, the application of a set of instruments, or tools, an artist, an archaeologist, and a collection of contrasting modes and techniques of observation and analysis. They conform to what Hayles (2017) terms "cognitive assemblages," in which human and nonhuman decision, or choice, making functions are distributed across, and link together, the component parts. Hayles makes a distinction between thinking and cognition. Thinking refers to high-level mental operations she associates with consciousness and unconsciousness, which are grouped together as modes of awareness enabling reasoning, abstraction, and the creation and application of, for example, languages, mathematics, art, and music. By contrast, cognition is a much broader capacity that extends far beyond consciousness into other neurological processes that also feature pervasively in other life forms and complex technical systems, especially in so-called artificial intelligences and scanning devices. Hayles refers to these broader and more widespread cognitive capacities operating below the level of consciousness as unthought or nonconscious cognition. What is perhaps most noteworthy about our art/archaeology artefacts is that they are the products of an intraacting cognitive assemblage in which the cognitive components do not simply interact in parallel or in tandem. Rather, we are consciously diffracting different modes of cognition through one another, human with nonhuman, conscious with nonconscious, artistic with archaeological practice and techniques, with the hopeful intention of producing surprises and unexpected results.

In humans, according to Hayles (2017, p. 27), nonconscious cognition comes online and is inherently much faster than consciousness. Its job is to interpret the constant floods of sensory inputs that would overwhelm consciousness and discern patterns that consciousness cannot detect and draw inferences to anticipate future events. This is perhaps why the chalk-coated 3D-printed "lithic" provokes such a strong negative reaction. The unthought expectation was that the object would have a certain feel and heft which, when it failed to match the anticipated cross-modal sensory pattern, caused a feedback loop to trigger consciousness (a half-second later) to pay attention to it. It caused us to pause and think. Changing the scale, material, colour, setting, or perspective of the artefacts shifts the register of cognition from nonconscious, or unthought, sense-making processes, into conscious attentiveness. One might think of it as deliberately priming a neural trigger for a new act of discovery.

Each individual art/archaeology *exhibit* presented here can speak for itself. We do, however, want to add a few closing remarks about the collection as a whole. Taken together, the bubblescape we have laid out reveals the *effects* of our diffractive art/archaeology practices. In these studies, we have probed into the shadows to discover new productive ways of radically disarticulating, disrupting, and repurposing fundamental features, or attributes, common to both art and archaeology assemblages. Authorship, provenance, temporality, setting, scale, and materiality have all been interlaced through one another. Who or what is the principle maker in these assemblages is now extremely difficult to pin down. Cognition has not so much been de-centred, rather human and nonhuman strands have been spliced together. Place, context, and setting also seep through one another from different perspectives, at simultaneously both macro and micro scales. Chronologies have been interfered with, and the very order of time and the nature of duration are unsettled. Our phygital (im)material exhibits unfold all these attributes and thus rearranged and transformed, they are returned to us for reinspection, recharacterisation, and recognition. These attributes of worlding, or world making, are not simple translations into comparable, or even remotely equivalent, representations. Our apparently simple lithic artefact has *metamophosed* into several previously undocumented "instars" (Ingold, 2020) whose ontological status is currently ambiguous, and whose affordances we are only just beginning to appreciate. Freshly emergent, they call to us for further study and novel phygital acts of discovery.

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