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‘I Can Do It’ Becomes ‘We Do It’: Kimberley (Australia) and Still Bay (South Africa) Points Through a Socio-technical Framework Lens

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Abstract
Building on the body of work regarding the concepts of invention and innovation in lithic technology, we further explore the give-and-take relationship between people and their technologies in two different stone point knapping traditions. From the socio-technical framework perspective, which is one amongst many ways to look at technological trends, the acceptance and stabilisation of a tool-making tradition is not only dictated by its technology-specific properties, such as its ingenuity or usefulness. Instead, it also depends on the social conventions and practices of its spatiotemporal context, which can be explored through the notions of introduction, closure, stabilisation, destabilisation and copying. We explain the theory behind the socio-technical framework with modern examples, such as bicycle use in late nineteenth century England and electrical guitar trends in the last half of the twentieth century. Turning our attention to stone point knapping, we use Australian Kimberley point production during the late nineteenth and twentieth centuries to bridge into how the socio-technical framework reflects in the dynamics that might be involved in lithic traditions. Using this theoretical framework to think about aspects of deep-time point production, such as that recorded from the Still Bay techno-complex during the Middle Stone Age in southern Africa, becomes trickier though. Instead of reliable ethno-historical accounts or dense archaeological context, we have to rely on coarse-grained data sets about distribution, age, environment and population, making inferences more speculative and less testable. In the context of this special volume, we suggest, however, that a socio-technical

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framework approach may be a useful tool to enhance our thinking about dynamics in ancient techno-behaviours and that more work is necessary to flesh out its potential in this respect.

Keywords Stone tools · Kimberley points · Still Bay points · Middle Stone Age · Socio-technical framework · Social negotiation

Introduction

A socio-technical framework structures interaction among members of social groups and shapes their thinking and acting towards a technological development. It comprises 'elements that influence the interactions within relevant social groups and leads to the attribution of meanings to technical artefacts—and thus to constituting technology' (Bijker 1995: 123). For a technological invention to become embedded in a society as part of their material culture, thus, as part of their socio-technical framework, it is necessary for it to become socially accepted and consistently performed throughout generations within a group and/or among different groups (Högberg 2009). This is so, even though social mechanisms for knowledge transmission and technical acceptance vary greatly across space and through time (Pfaffenberger 1992). Key to development in human cultural evolution (Mesoudi and Thornton 2018) was therefore not individual capabilities in tool invention, production and use in itself, but the traditions that emerged when technologies, such as stone tool production strategies, became socially accepted and transmitted between generations through intentional teaching (Gärdenfors and Högberg 2017). Hence, when thinking about how new technologies became persistent in a social setting, and as such visible and prevalent in the archaeological record, and to understand what could have led to their demise, we suggest that it may be useful to focus on their acceptance in society, as in 'we do it' instead of on their invention, as in 'I can do it' (Table 1).

This thinking connects with ideas about invention (a new creation) and the subsequent wide-scale social acceptance of that creation, which is often innovated (improved upon or adapted into new ways of doing). This distinction between invention and innovation was established in economic theory by Schumpeter (e.g. 1939), who described discoveries and inventions as events that create new possibilities counting among the most important causes of socio-economical change. Yet, invention does not

Table 1 Distinction between 'I can do it' and 'we do it' in a lithic context

	Explanation	Example
I can do it	Discovery of a new knapping strategy; individuals performing the skill associated with this knapping strategy.	An individual experimenting or a group of experimenting stone knappers discovers the advantages of pressure flaking when making thin, bifacial points.
We do it	Institutionalised way of how to perform; new knapping strategies are accepted as common practice through social agreement; strategies and associated knowledge and skills become social norm, within a group and across a landscape.	Practices as, e.g. intentional teaching, have been established that facilitate inter-generational (through time) and inter-group (across the landscape) knowledge transfer associated with the technology of pressure flaking.

necessarily induce innovation and innovative behaviour is possible without an invention, which of itself has no socio-economic consequence. For Schumpeter (1939: 80), innovation represents 'changes in the methods of supplying commodities'. Thus, a range of events that include the introduction of a new product to society, technological change in existing productions, the opening up of new users/supply chains, increased work efficiency, improved material handling and expanding the reach of the commodity or technology (also see Ruttan 1959; Parayil 1991; Sundbo 1998).

Renfrew (1978: 90) incorporated these concepts into archaeological theory, describing inventions as 'the discovery or achievement by an individual of a new process, whether deliberate or by chance'. On the other hand, he sees nearly every technological innovation as also a social one characterised by its wider production and use. '[T]he necessary matrix for the development of technological innovations […] is dependent on social relationships […] They depend upon values, ordered values, and upon rules of conduct and behaviour. These in turn are regulated by social roles and by distinctions of status […] They are dependent on shared understandings among humans within a community, understandings which are at once social and cognitive' (Renfrew 2001: 97). As a result of this, he suggests that valuable technological advances may lie untapped for long periods or take long to reach its full potential. Spratt (1989) also highlighted differences between innovation processes in modern industrial conditions and ancient societies. He argues that although benefit/cost ratios in ancient contexts were high, innovations spread slowly and that long delay times often occurred as a result of a range of 'cultural factors'. In the case of modern innovation, the opposite is the case.

Although relationships between population size and cultural complexity are not straight forward (Collard et al. 2005, 2016; Vaesen et al. 2016), it appears that innovation in the context of the Stone Age/Palaeolithic might have been more successful in larger populations than in smaller ones. For example, Shennan (2001) showed that Stone Age innovations associated with the origins of modern humans were a result of demographic growth and an increased contact range (Shennan 2001). This links to the outcome of Fitzhugh's (2001: 157) study that concluded that 'technological innovation under crisis conditions would more often fail than would innovation under times of security. This paradox could help explain why technological change is relatively slow through most of human prehistory. As population density increased relatively late in prehistory, there would have been more people to generate inventions and successful innovations would spread more rapidly due to greater facility of cultural transmission'. Similar approaches are widely used in behavioural archaeology (e.g. Skibo and Schiffer 2008).

Hovers and Belfer-Cohen (2006: 299) have argued that the emergence of modern human culture may appear erratic because techno-behaviours become visible in the archaeological record 'only after appropriate cues in the social and physical environments have triggered the passage from latent potential [invention], to actualised behaviour to prevalent norms [innovation]. Once the initial trigger kicks in, the particular behaviour appears. However, in order for such a behaviour to *persist* [their emphasis], the pertinent knowledge must be retained and transferred down the generations' (also see Hovers 2009 for application to lithic analysis). Tostevin (2003, 2012) assessed the notion of independent innovation as opposed to cultural transmission being the prevailing process/es for the Middle to Upper Palaeolithic transition between about 60,000 and 30,000 years ago in Europe and the Levant, finding that his results supported a cultural transmission hypothesis rather than an independent innovation hypothesis. Moving even further back in time, Meignen (1998: 159) suggested that the appearance and disappearance of, for example blade technologies since 200,000 years ago in the Levant until their proliferation during the Upper Palaeolithic, was not dependent only on knowledge transfer about the manufacturing of discrete technological traits, but rather on the 'social/demographic environment that formed the necessary preadaptations for the acceptance and ultimate dominance'.

Below we build on these foundations and consider how we can enrich our understanding of what might be involved in processes leading from 'I can do it' to 'we do it'. We do so by exploring Bijker's (1995) socio-technical framework and his terminology of introduction, closure, stabilisation, destabilisation and copying. We start with modern examples of bicycles, pneumatic tyres and electric guitars. Then we move on to discuss aspects of the socio-technical framework in relation to lithic point production, because points and point production have been suggested to act as 'micro-cosmos' for society-wide transformations of different geographic scales and in various contexts (e.g. Wiessner 1983; Mjærum 2012). Clark (1988), for example, suggested that variation in 'regionally distinct bifacial and unifacial point forms' may signal aspects of population identity during the Middle Stone Age of East Africa (also see McBrearty 2007 on the role of points in catalysing the cultural geography of human groups). First, we use Australian Kimberley points from the late nineteenth and twentieth centuries as a bridge into how a socio-technical framework may be reflected through lithic technology—in particular point production. Then, we explore the possible origins, acceptance and demise of Still Bay point production in southern Africa more than 70,000 years ago through a socio-technical lens.

Although Kimberley and Still Bay points have typological or even stylistic integrity in modern archaeological analyses, we use them instead as examples of 'strategies in information exchange' as discussed by Wobst (1977; also see Högberg and Lombard 2016a). By doing so, we embrace the traditional archaeological notions of technical/typological categories, but similar to Wobst's, our take is more inclusive, reaching beyond a narrow view of 'type'. Working with material from southern Africa, Thackeray and Kelly (1988: 23) suggested that the Middle Stone Age stylistic/typological attributes recognised by archaeologists are 'a reflection not of social reality, but rather the structuring principles of the society—the way things might be ideally—rather than the way they are in practice'. This way of thinking about a technology or artefact category allows for a broader theoretical perspective, with which we hope to stimulate discussion about the multifaceted articulations between technology and society. In line with the theme of this special issue, our aim is not to provide a new method for analysis (for our body of work on method and data development relating to the Still Bay techno-complex we refer readers to Högberg and Lombard 2016a, b; Lombard and Högberg 2018; Lombard et al. 2019) or to present ultimate answers. Instead, here, we use the socio-technical framework as a 'new thinking tool' (in the context of the Kimberly and Still Bay points) to develop ideas about the possible interplay between 'old technologies' and historical or ancient societies.

Socially Negotiated Ways of Doing: the Socio-technical Framework

Human actions are performed by individuals with a certain degree of autonomy, but as discussed above, they are also largely influenced by the structuring practices of the social group (Giddens 1984). The relationship between them is dialectic and the process formative—individual actions are affected by structuring factors, which in turn consist of the results of actions (Lemonnier 1993). Actions, innovation and technology are closely linked and the archaeological record reveals, with the words of Geselowitz (1993: 232), 'a past full of constant change in technology'. As Dobres (2000: 132) notes, this demands from archaeology an 'explicit concern with the social and meaningful "becoming" of artifacts through material grounded activities conducted by technical agents and mindful communities of practice' (also see Meskell and Preucel 2004).

To develop our thinking on what might be involved in processes that turn 'I can do it' into 'we do it', we here address technological change and persistence by taking archaeological theory into account. The socio-technical framework we draw on was developed within science and technology studies (Pfaffenberger 1992) and brought into archaeology by, for example, Geselowitz (1993). First presented as 'social construction of technological system' (Pinch and Bijker 1984; Bijker et al. 1987) and 'socio-technical systems' (Pfaffenberger 1992), Bijker (1995, 2006a, b) with others (Law 1992; Law and Bijker 1992) developed a 'socio-technical framework' to explain the social shaping of technology and the technical shaping of society (Bijker 1995: 11). This way of looking at technology recognises that there are no pure or unadulterated social relations, in the same way as there are no absolute technologies. Both social relations and technologies are seamlessly entangled in complex mutual feedback relationships between humans, their environment and material culture (Latour 1992, 2007). Law (1992: 3) stresses that when humans form social networks, it is not because they interact with each other. It is because they interact with each other and an endless array of other materials too (see also Högberg 2009).

Here, we explore the potential of this theoretical framework for Palaeolithic archaeology by applying it to a discussion on change and persistence in lithic technologies and knowledge transfer systems, building on our previous theoretical work (Högberg 2009; Högberg and Larsson 2011). In this context, our exploration should neither be understood as a search for static models to explain prehistoric processes nor as a model that excludes other interpretative frameworks, such as function, cost-efficiency or ecological niche creation. Rather, it is used as a conceptual tool to think through the social acceptance of knapping conventions as one of many aspects of human material engagement. It goes without saying that the purpose of our endeavour is not to impose modern conditions onto prehistoric everyday life but to broaden our thinking about it. Thus, we take a more cautionary stance compared to those who see the socio-technical framework as a tool to 'integrate anthropological finding about preindustrial societies into a coherent picture of the universals of human technology' (e.g. Pfaffenberger 1992: 493).

Introduction, Closure and Stabilisation

The invention of technologies happens in many ways—responsive elaboration, amplification, trial and error, unintended chance, curiosity testing and play are some examples described in human evolutionary studies (e.g. de Beaune 2004; O'Brien and Shennan 2010; Haidle and Bräuer 2011; MacDonald 2011; Akazawa et al. 2013; d'Errico and Banks 2013, 2015; Mesoudi and Aoki 2015; Nowell 2015; Riede et al. 2018). As mentioned, for a technology to become part of everyday societal life, the act of invention in itself is not enough (Renfrew 1978). The new technology also needs to be introduced into a wider social setting, beyond the context of its 'discovery' or improvement.

As soon as a new technology is introduced, it becomes a subject of social negotiation. Such negotiations take place from various positions with a wide range of purposes. Within the social and material networks involved in the negotiation, a give-and-take between people and technologies emerges. These negotiations are not solely bound to technology-specific properties, such as the efficacy, productivity, proficiency or individual preferences, but also relate to social regulations and practices. Negotiations involving tradition and invention often result in periods of flexibility in how technologies are understood. Many inventions are never introduced or accepted outside of its creation, that is to say, technologies invented do not become widely used—despite their possible ingenuity.

If the invention is not rejected by the broader society, a technological closure happens across groups within a society or across societies. Here, an accepted social understanding of what constitutes the technology is established. Any previous social flexibility is significantly reduced or disappears. The technology is now in a state of stabilisation, which means that discussions/negotiations are no longer needed about its place and meaning in society. This technological stabilisation can vary between different social groups (Bijker 1995). If a stabilisation process leads to a closure that lasts for a very long time, that is, when inter-generational knowledge transfer happens for generation after generation without any considerable change, the technology has become an institutionalised way of how to perform, a social norm within a group and across a landscape.

An example is the high-wheeled ordinary or penny-farthing bicycle (for a comprehensive description, see Bijker 1995). With a big front wheel, a small rear wheel and the saddle mounted almost directly on top of the front wheel, it was a particularly unsafe bicycle. If the front wheel hit a stone, for example, the bicycle easily overturned, flinging the cyclist headlong over the handlebars. Injuries thus sustained contributed to the 'unsafe' reputation of the high-wheeled ordinary. The safety bicycle, resembling today's bicycles, with two wheels of about equal size and the saddle placed roughly halfway between the wheels, was introduced as a less dangerous alternative. For young men from the British upper class, however, wanting to show off their bravery to ladies in public parks each weekend, riding a safety bicycle would have resulted in social ridicule. For a display of courage, the high-wheeled ordinary was essential. Without the dangers associated with this bicycle, there was nothing to be valiant with. The penny-farthing thus became a 'macho bicycle', and the safety bicycle was rejected socially in the context of British manly display (Bijker 1995).

When the pneumatic tyre was invented by the end of the nineteenth century, it was introduced with the specific purpose of reducing vibrations in bicycles. The target group was broad—all cyclists. But these tyres were rejected by society, because vibrations were not thought to be a sufficiently serious problem to justify replacing cheap and durable solid rubber tyres with more expensive and fragile pneumatic tyres. When pneumatic tyres were, however, introduced as fitted to racing safety bicycles, it turned out that they had another advantage—they were faster than solid rubber tyres. This success for the tyre in competitive sport started a negotiation of the innovation that quickly changed the technology from an 'anti-vibration' tyre to a 'high-speed' tyre. Because of this change in value perception, the pneumatic tyre became popular, and within a few years, virtually all solid rubber tyres were replaced with pneumatic tyres. The technology came to a closure. Simultaneous to pneumatic tyres becoming the standard for safety bicycles, young men still riding the high-wheeled ordinary in racing competitions started to lose. The safety bicycle fitted with pneumatic tyres became a 'winning' combination. The 'macho bicycle' now turned into a 'looser bicycle', and the technology of safety bicycles with pneumatic tyres was stabilised and became the socially accepted norm (Bijker 1995).

What this example shows is that the way an invention becomes something that is socially accepted is not simply dependent on the act of invention or on it being useful. Neither the safety bike nor the pneumatic tyre was accepted when invented—regardless of them being indisputable technological improvements. These technologies only came to a closure once they were introduced and successful within a specific social context that was important enough to attract attention and prestige, such as the bicycle race.

Destabilisation, Copying and New Closure

Once accepted, technology continues to develop and/or change in interaction with the social network in which it is used. This interaction is not just about introduction, closure and stabilisation; technologies are also rejected, destabilised or copied and brought to new closures. In other words, through time, society gives new meanings to technologies that lie outside the consensus of previous closures. Rejection or destabilisation implies that the meaning formerly ascribed to a technology by stabilisation no longer applies. Copying is when a technology is duplicated, distressing the stabilisation of the technology and gives it ambiguous new dimensions (Bijker 1995).

Högberg (2009) uses the world-famous Fender Stratocaster electric guitar, launched in 1954, to illustrate these socio-technical interactions. Iconic musicians, such as Jimi Hendrix and Eric Clapton, helped to make the 'Strat' immortal. But it is an expensive instrument. Dependable technology, high-quality materials and meticulous craftsmanship are invested in every guitar. Because of its popularity in combination with its high cost, the Stratocaster became one of the world's most copied guitars. Countless manufacturers all over the world have launched replicas. The market success of Stratocaster replicas resulted in the producer of the original instrument releasing their own replica, known as the Squier Stratocaster. The copy looks similar to the original, but is cheaper, produced with lower-quality technology. In little more than 60 years, societal demands transformed the guitar once launched as the Fender Stratocaster from a high-end model to a 'concept' that now includes a host of artefacts with very different qualities.

What this example shows is that copying complicates or adds new dimensions to how society perceives and uses technology. What was perhaps socially agreed upon during initial closure can be changed through processes of copying. Innovations are developed, expanding on original intents, starting the destabilisation process. This usually implies that there are at least two alternatives for the future. Either the destabilisation will result in the disappearance of the original technology or new closure processes will start. New and old perceptions about the technology are again aligned with social negotiation that successively moves towards stabilisation. This can in turn lead to further development or change to adapt the technology to suit new demands entailed by destabilisation (Bijker 1995).

Knapping Traditions Considered Through a Socio-technical Lens

Australian Kimberley Point Production in the Late Nineteenth and Twentieth Centuries

People of the Kimberley region in north-western Australia (Fig. 1) made stone points using direct percussion from about 5000 years ago, but from roughly 1000 years ago, bifacially retouched and pressure flaked ‘Kimberley points’ appear in the archaeological record (Maloney et al. 2014; also see Harrison 2004), often with denticulated or serrated margins (e.g. Akerman and Bindon 1995) (Fig. 1). This represents a major change in point-production strategy, and on a regional scale it seems that the introduction of pressure flaking happened earlier in the southern Kimberley than in the Northern Territory. In the latter area, pressure flaking only started to be used by some groups as late as the 1930s (Maloney et al. 2014). The appearance of pressure flaked points across the Kimberley region, however, at 1000 years ago may represent their proliferation and technological closure as described above, which does not preclude that older points may yet be found at isolated sites.

Kimberley points were produced and used mainly (but not exclusively) as spearheads for fighting, hunting and exchange. Most of these spear tips are less than 6 cm long, made to dislodge from their shafts during fighting or hunting to stimulate bleeding or infection (Akerman et al. 2002). The ethno-historical record indicates that point production was a key activity for men during the times that they were not participating in hunting or ceremonial performances and that large, elongated pressure flaked points were made mostly for exchange purposes along indigenous trade and exchange networks (e.g. Fullagar et al. 1996). Such networks had goods moving initially within the range of kin and personal exchange partners, subsequently filtering to adjacent groups maintaining complex, prehistoric systems of reciprocity, rights and obligations among people and groups (Akerman et al. 2002: 22). Men thus gained access to points made from various materials across the region through their exchange-network partners.

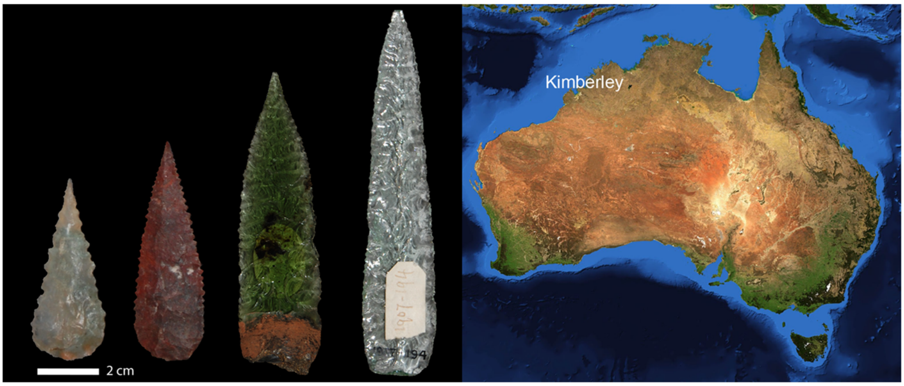

Fig. 1 A selection of Kimberley points curated by the British Museum, the two to the left are made of stone, the two to the right are made of glass (images used with permission © Trustees of the British Museum) and a map indicating the Kimberley region of Australia

Akerman et al. (2002) further use Australian oral tradition to show how the production of stone spearheads are intimately linked with social organisation and myths of their origin. The stories relate how the first hunting spears were wooden spears, and that although stone spearheads used with spearthrowers were a great improvement, they were initially simple, thick and heavy. Some groups attribute the introduction of stone spearheads to mythical animal creatures, improved upon by humans: 'Invasive retouch using pressure led to refinement of symmetry. The use of bone indentors permitted the creation of denticulations or serrations and further enhanced the lacerating potential' (Akerman et al. 2002: 17). Clendon (1999) suggested that the material and level of 'refinement' used for point production could reflect its mundane or symbolic function/s, with finely serrated points made on shiny or translucent stones often made not for hunting but rather for the magical or curative power derived from their aesthetic value (Fig. 1; also see Harrison 2002). Akerman et al. (2002), however, observed such spears also being used for hunting, but confirm that large white Kimberley points made on heat-treated chalcedonic silcrete from the 'blacksoil plains' were made exclusively for trading with partners to the south east of their origin, where they were used as ceremonial knives for purposes such as circumcision (also see Harrison 2002).

Indigenous law dictated the rules of point flaking; as a result, only initiated men were allowed to make pressure flaked Kimberley points (e.g. Kaberry 2004 [1939]). They were therefore a symbol of adult manhood, and displaying skill in their manufacture served as a way to gain status and prestige (Harrison 2002). For example, when groups of different indigenous languages met, men would showcase their best-made points by laying them out on the ground to be admired by others or in a peacock-like display fan their spears behind their bodies before the hunt or ritualised fighting (Harrison 2002). It further seems that having control over valued raw material sources for point production provided older men with socio-economic authority in the Kimberley and the adjacent Arnhem Land (e.g. Taçon 1991; Harrison 2002). Such power over natural resources was a fundamental aspect of indigenous Australian masculinity. Through the hunt, male display and initiation ceremonies (such as circumcision), as well as through resource control, several aspects of Kimberly point production and use seem to have been inextricably linked to notions of manliness and masculinity (Harrison 2002). Thus, since pre-colonial times, the socio-technical materiality of Kimberley points was used to signify, sustain and negotiate values and belief systems.

European settlers moved into the Kimberley region relatively late, compared to other areas along the Australian coastline. Harrison (2002: 355) writes that: '[…] much of the Kimberley region was taken up for cattle (and some sheep) grazing by 1900, and Aboriginal people formed a major labour source for this extensive and labour-intensive form of pastoralism. Aboriginal people often formed large community camps on the edges of pastoral stations'. In Kimberley, Australian indigenous groups were normally able to settle on stations that allowed them access to their traditional country, enabling them to undertake traditional activities and ceremonies.

Set against this background, the production of Kimberley points intensified during early contact with European settlers, and bottle glass was introduced as a new raw material from which to manufacture them (Fig. 1). Harrison (2002) argues that in response to rapid and drastic social change throughout the early stages of contact between indigenous Australians and European settlers, ways to redefine traditional expressions of status and personal identity developed. During this phase, 'men needed to find ways of expressing self-worth and to develop a sense of identity that was not dependent on hunting' (Harrison 2002: 368). It seems that their skill to manufacture beautifully pressure flaked points was one way to express their dignity at the same time as hunting became a less important subsistence practice. Harrison (2002, 2006) argues that the introduction of bottle glass for point production must have impacted on the age-old societal fabric and power relations of indigenous groups. Now resources were no longer controlled in the traditional manner but became available to men of lesser influence through their nearness to colonial settlements and glass (Harrison 2002, 2006).

Consequently, profound socio-technical changes/destabilisation took place that fundamentally transformed technological systems of knowledge transfer, altered established trade networks and created new social relations. One of the main reasons for this, besides colonial occupation of the landscape, was that Europeans brought with them the practice of collecting things and information. As in many other parts of the colonised world, social Darwinism theory saw indigenous lifeways as trapped in a natural and irreversible state of decline, and thus as dying out (Pigott 1975). Collecting, as systematic scientific endeavour, was regarded as a way to save remnants of indigenous lifeways, before they vanished completely (Hodacs et al. 2018). Taking souvenirs was also a way for many Europeans to obtain the curiosities of indigenous groups to show off to their contemporaries or to display in their homes and/or museums. From the late nineteenth until the second half of the twentieth century Kimberly points, especially large glass ones, were collected and merchandised, first by/for private collectors and then also for museums across the globe (Harrison 2006; Fig. 1). Thus, many Kimberly points in collections today had no purpose other than to serve as collectables (Harrison 2006). As a result, indigenous entrepreneurs started to produce points explicitly for this market (see Harrison 2002 for discussion). Such production was built on new social relationships that involved market demands for what was seen as authentic indigenous artefacts. European collectors particularly also appreciated the beauty of large colourful glass points, skilfully manufactured and invasively pressure flaked over both faces. Consequently, such points were increasingly produced to meet 'market demands'. Once the curiosity about the way in which the points were made was satisfied, the market saturated, and indigenous people found different, more lucrative ways to situate themselves in the curio market, the tradition ended.

Considered from a socio-technical framework, the tradition of Kimberley point production represents a lithic technology that within the last 1000 years went through all the stages discussed above. First, the innovation of pressure flaking was introduced as a way to make lighter, more effective spearheads with increased lethality. The technology was accepted and brought to a closure in the Kimberley region by becoming a widely accepted way of doing things and even traded further afield where their beauty was associated with supernatural power or meaning. Indigenous Australian law, customs and power relations ensured that the technology was stabilised and embedded within age-old concepts of masculinity, ensuring that flexibility and variation in approaches to point production was curbed—Kimberley points became an institutionalised tradition.

From around 1885, new socio-technical relations triggered the destabilisation of these older traditions. Power relations within indigenous communities changed. In a socio-technical negotiation: 'younger men pursued relationships with European settlers to gain access to glass raw materials so that they could bypass the control of stone by older men'

(Harrison 2007: 134). Copying an older technology with a new raw material resulted in the introduction of new materiality—long, elaborately produced glass points of Kimberly type. Hence, an older socio-technical closure was destabilised. The copied technology using new materials produced a product for new social relations, which were established on a new market system. The process overturned previous power relations as well as the status and prestige related to them. The high market demand for the beautifully produced Kimberley points brought this technology to a quick new closure.

Harrison (2002: 369–370) further argues that 'The increase in frequency of manufacture of points in the contact period appears to be at least in part associated with changing symbols of masculinity associated with coming to terms with new ways of life on fringe camps, where large groups of people were often camping in close quarters. On pastoral stations in the Kimberley, Aboriginal men were increasingly drawn into a social world that emphasized individual action as a way of gaining prestige. This largely stood in opposition to traditional ways of gaining status that would have taken into account age and gender, and would have been specific to a particular place or social forum. The emphasis on the skills of individual stockmen in cattle work thus produced a social system which was focused on individual skill, rather than position within the group'. Such a silent renegotiation of masculinity is an example of how the knapping skill of young indigenous men were used to influence social behaviour towards them and helped them to adjust to social issues associated with contact period interaction. In traditional social contexts, the new elongated glass point technology was rejected, because they were seen as inferior in hunting and fighting compared to points manufactured from specific stones that were linked conventionally to manly power and efficiency. Hence, in this setting, stone had a socio-technical prestige that glass lacked (Harrison 2002, 2007).

Notwithstanding rejection by some traditionalists, exchange by collectors and museums quickly transformed Kimberley points into a 'commodity for exchange between Australian and foreign museums' (Harrison 2002: 364). Simultaneously, descriptions of Kimberley points also began to appear in academic publications (Harrison 2006). As objects of academic writing and inventories in museum collections, these points reached stabilisation. Within a few decades, the technology had come to a new, and apparent long-lasting, material closure as typological definitions in academic writing, permanent museum exhibitions and as objects in museum storage with linked information in accession catalogues.

What this example shows is that over a few decades points were transformed from a product of deep tradition to a concept—Kimberley points—that now also included artefacts with new, very different qualities compared to before. After about 1930, the market for invasively pressure flaked points seem to have become satiated. Because these points were made mostly to satisfy a European collectors' market, their production became increasingly rare. More recently, analysis of ethnographic museum collections are used in discussions on the emergence of stone-tipped projectile weaponry in human evolution (Newman and Moore 2013). Also, academic interest in post-colonial theory-initiated discussion about the interpretation and meaning of Kimberley points from a historical and contemporary perspective contribute to new negotiations about their meanings, and once again starting a destabilisation process (Harrison 2006 with comments). Hence, the technology takes on new forms of social meanings in scientific analysis and discussion.

Southern African Middle Stone Age Still Bay Point Production

The Kimberly example is rich and detailed, especially regarding aspects of its more recent history. But, can the socio-technical framework also be useful in thinking through aspects of point-production instances with greater time depth where different—thus far unknown—social mechanisms for knowledge transmission and stabilisation were almost certainly in play (see Bader et al. 2018 for discussion)?

From the discussions presented above on bicycles, tyres, guitars and Kimberley points, phases in the socio-technical framework can be used to make predictions about the manifestation of material evidence (Table 2). Here, we use Middle Stone Age Still Bay points to elaborate on this topic. The Still Bay is typified by thin, invasively retouched, bifacial, foliate or lanceolate points with semi-circular or wide-angled pointed butts and lenticular cross-sections (Goodwin and van Riet Lowe 1929). Some were pressure flaked (Mourre et al. 2010; Högberg and Lombard 2016a, b), and some have finely serrated edges (for analytical processes and data see Lombard et al. 2010; Fig. 2). This is a narrow definition for Still Bay points for the benefit of a general readership, but we continue the line of broad theoretical thinking about tool class discussed in our introductory section, in our subsequent scenario building (also see Lombard and Högberg 2018; for our understanding of more narrow typological, technological and morphometric units, which fall outside of the scope of this paper, see Högberg and Lombard 2016a; and Lombard et al. 2019). Needless to say that, like any other definition in the discipline, this is a modern archaeological construct and does not reflect any ancient 'reality' (Thackeray and Kelly 1988; Högberg 2009).

A large body of work has established the Still Bay as a recognised lithic tradition in the southern African sequence (Minichillo 2005; Wadley 2007; Villa et al. 2009; Högberg and Larsson 2011; Lombard et al. 2010, 2012; Henshilwood 2012; Porraz et al. 2013). Based on a range of cultural material, the broad Still Bay cogni-behavioural repertoire has been demonstrated not to be unlike that of more recent hunter-gatherers (e.g. Henshilwood 2012; Lombard 2012; Wadley 2015), and some Still Bay points were used to tip hunting weapons (e.g. Lombard 2005, 2006, 2007). We have previously argued that technological similarities and variation in Still Bay point production might indicate broadly shared, as well as locally constrained,

Table 2 Phases in the socio-technical framework and predictions that can be made about the manifestation of material evidence in relation to Still Bay point production

Phase	Prediction
Introduction	The production and/or use of a technology beyond its invention; thus, it must be reasonable (based on the archaeological record) to accept that more than one person or a group of experimenting stone knappers produced/used a specific technology across space and/or through time.
Closure	Evidence for society or group-wide use of a specific technology.
Stabilisation	Evidence for less variation and flexibility in a specific technology class, as a result of becoming an institutionalised tradition through ways of teaching and learning or any other social norms.
Destabilisation	Evidence for the copying of, or changes in, the production or meaning of a specific technology class.

Fig. 2 From left to right, Still Bay points from the site Apollo 11 Rock Shelter, Sibudu Cave, Hollow Rock Shelter and Umhlatuzana Rock Shelter, and a map with sites with Still Bay assemblages discussed in the text (modified from Lombard and Högberg 2018; Lombard et al. 2019). The black dot on the Cape Peninsula, bottom left on map, marks the approximate locations of Peers Cave and Dale Rose Parlour

traditions and variability in knowledge transmission (see Högberg and Lombard 2016a; Lombard and Högberg 2018 for analytical method and data), and most researchers also agree that the particulars inherent in the point assemblages of the techno-complex might ultimately be used 'to identify cultural affiliation amongst contemporaneous bifacial point producing groups, and the geographic context within which this may be appropriate' (Archer et al. 2016: 69). Yet, without knowing more about the socio-historical context/s in which Still Bay points were made and used, interpretations remain poorly informed (Bader et al. 2018).

With our recent diachronic work on point production at Sibudu Cave (Lombard et al. 2019), we have also demonstrated that, contrary to some interpretations (e.g. Jacobs et al. 2008; Jacobs and Roberts 2017), the production of Still Bay-type points was not an abruptly appearing, short-lived techno-behaviour. Instead, at Sibudu knappers made points that fit the Still Bay definition for at least about 7000 years. Looking at the age estimates of other sites with dated stratigraphy, such as the Blombos Cave and Diepkloof Rock Shelter (Table 3), a sudden and discontinuous interpretation of the Still Bay (based on the tweaking of dating statistics) also seems implausible. Here, we use the socio-technical framework to think through and hypothesise about possible scenarios that might have affected the introduction, stabilisation and demise of Still Bay point production.

In lieu of more direct lines of evidence, such as ethno-historical records, exploring systems for transmitting and maintaining cultural innovations in deep-time contexts benefit from including a variety of factors (e.g. d'Errico and Banks 2013). For our examples of socio-technical scenario building for Still Bay points, we use the sets of luminescence ages presented in Table 3. Acknowledging that there are variations in resolution for values used (plus/minus effects for each age estimate), as well as unresolved dilemmas when results from different laboratories are compared (e.g. Guérin et al. 2013; Tribolo et al. 2013; Jacobs and Roberts 2015, 2017), we use the published data simply as possible chronological markers to hypothesise how shifts in time/data sets may affect scenario building. Similar to the age estimates, we use the palaeo-climatic reconstructions derived from the Lake Malawi drill core as putative and very broad ecological background for our speculation (we recognise, however, that

Table 3 Luminescence ages used in the text. Note that the two age estimates from Apollo 11 are from the same value, analysed with different methods. Therefore, they are treated as one in Fig. 3. First line for each site show the youngest-oldest values as illustrated in Fig. 3

Site	Age estimate	Source
Apollo 11	70 ± 2.9	
	70 ± 2.9	Jacobs and Roberts 2017
	71 ± 3	Vogelsang et al. 2010
Blombos Jacobs	71.9 ± 3.7–76.0 ± 3.8	
	71.9 ± 3.7	Jacobs and Roberts 2017
	72.0 ± 3.4	Jacobs and Roberts 2017
	72.3 ± 3.5	Jacobs and Roberts 2017
	72.4 ± 3.7	Jacobs and Roberts 2017
	72.8 ± 3.1	Jacobs and Roberts 2017
	74.1 ± 3.4	Jacobs and Roberts 2017
	74.1 ± 3.6	Jacobs and Roberts 2017
	74.3 ± 3.8	Jacobs and Roberts 2017
	76.0 ± 3.8	Jacobs and Roberts 2017
Diepkloof Jacobs	70.8 ± 2.3–76.5 ± 3.3	
	70.8 ± 2.3	Jacobs et al. 2008
	73.6 ± 2.5	Jacobs et al. 2008
	76.5 ± 3.3	Jacobs and Roberts 2015
Diepkloof Tribolo	100 ± 8–113 ± 8	
	100 ± 8	Tribolo et al. 2013
	101 ± 11	Tribolo et al. 2013
	102 ± 10	Tribolo et al. 2013
	104 ± 10	Tribolo et al. 2013
	108 ± 10	Tribolo et al. 2013
	110 ± 10	Tribolo et al. 2013
	112 ± 9	Tribolo et al. 2013
	113 ± 8	Tribolo et al. 2013
Hollow Rock Shelter	72 ± 4–80 ± 5	
	73 ± 6	Feathers 2015
	72 ± 4	Högberg 2014
	80 ± 5	Högberg 2014
Sibudu	70.5 ± 2.4–77.2 ± 2.6	
	72.4 ± 3	Jacobs and Roberts 2017
	70.5 ± 2.4	Jacobs et al. 2008
	72.5 ± 2.5	Jacobs et al. 2008
	77.2 ± 2.6 (‘pre-Still Bay’ with Still Bay points)	Jacobs et al. 2008
Umhlatuzana	70.5 ± 4.7	
	70.5 ± 4.7	Lombard et al. 2010

southern Africa experiences slightly delayed climatic shifts compared to those in East Africa, largely due to the proximity of the southern tip of the continent to Antarctica [e.g. Pickford 2004]), and the recently summarised pollen data for South Africa to illustrate regional variability (Scott and Neumann 2018; and Table 4), also referring to a synthesis of South African coastal plain sea-level fluctuation that may have affected population movement between the southern and western coastal plains of the Cape (Compton 2011 Table 1: 515).

It is understood that environmental/climatic conditions in southern Africa were more varied/complex than represented by these data sets, as illustrated by more fine-grained work for later periods (e.g. Chase and Meadows 2007; Chevalier and Chase 2016; Quick et al. 2018). Here, we use these environmental data sets merely as illustration of how to incorporate a range of elements into socio-technical thinking and not as comprehensive analysis. Further, the population estimates for hunter-gatherer ancestry in southern Africa, as recently calculated from the DNA of a boy from Ballito Bay (Schlebusch et al. 2017: Fig S18; Lombard et al. 2018), provide the best current data for (reproductive) population sizes spanning the Still Bay. Thus, what we present below can be nothing more than hypothetical scenarios. Yet, as more localised, fine-grained data become available (e.g. for the Still Bay itself, as well as for sub-continental climatic conditions and variations, and for changes in the demography), the principles we discuss here in theory can be assessed, strengthened and/or constrained to formulate increasingly nuanced impressions of the socio-technical dynamics at work. For example, the dating of Still Bay assemblages at sites such as Peers Cave or Dale Rose Parlour, or the publication of full data sets for all the points (as well as technological analyses of the full assemblages) from the Blombos Cave and Hollow Rock Shelter Still Bay sequences, may help to refine any of the scenarios we present. Especially in the case of Blombos, a full temporal technological analysis of all its points and point fragments (see Archer et al. 2015 for morphometric analysis of bifacial pieces), comparable to what we have done for Sibudu Cave (Lombard et al. 2019) would be important in light of the new environmental proxy data for the site (e.g. Roberts et al. 2016). Thus far, however, these data (despite showing changes in vegetation, aridity, rainfall seasonality and sea temperatures) show that although they may have impacted on subsistence, they 'did not directly influence technological or cultural innovation' (Roberts et al. 2016: 16; contra Ziegler et al. 2013). This is consistent with our finding for the temporal spread of Still Bay point making at the Sibudu Cave (see Lombard et al. 2019 and discussion below).

If we accept the Tribolo et al. (2013) age estimates for Diepkloof (Table 3, Fig. 2), then people could have started to make Still Bay-like points at the site during the early stages of MIS 5d at 113 ± 8 ka and continued to do so for about 13,000 years until deep into MIS 5c at 100 ± 8 ka. According to this scenario, it seems that Still Bay point production was introduced roughly contemporaneously with an extreme drought phase recorded at Lake Malawi for MIS 5d (Fig. 3), associated with a shift from leaf- to grass-dominated vegetation from about 111.8 ka as evidenced through the local pollen record (Scott and Neumann 2018). Periods of extreme drought also continued throughout MIS 5c, with lake levels at its lowest during this time and evidence of semi-desert conditions in the adjoining lowlands. The South African pollen record also indicates a shift away from woodland/forest environments and rainfall that is more seasonally restricted during this time (Table 4; also see Scott and Neumann 2018). For the making of Still

Table 4 Summary of the Lake Malawi drill core and South African pollen record palaeo-climate reconstruction during MISs 4–5

Lake Malawi as broad sub-Saharan setting	Southern African pollen record as regional variants
MIS 4; ~ 59–73 ka; generally cool	
•Evergreen woodlands started increasing during MIS5a at ~ 75 ka, and continue to do so until ~ 65 ka •Up to ~ 71 ka the lake is still characterised by fluctuating levels, which were much higher than those of the mega-droughts centred at ~ 100-130 ka •After ~ 70 ka climate shifted to more humid conditions and lake levels rose •MIS 4 is a relatively cold period with temperatures generally decreasing from 25.5 °C at 68 ka to a minimum of 20 °C at ~ 60 ka, 1.5–2 °C colder than the Last Glacial Maximum (LGM), followed by a rapid increase of 3–4 °C in only ~ 0.5 ka •From ~ 60 ka, there is an expansion of Afromontane vegetation (Beuning et al. 2011; Scholz et al. 2011; Woltering et al. 2011)	•Indian Ocean region: percentages of woodland pollen remain low and *Podocarpus*, a humid element, is gradually retreating; more Asteraceae and Poaceae pollen percentages point to rather dry conditions •Interior: After ~ 73 ka, conditions became cooler and probably drier; after ~ 63 ka, a cool grassy phase changed sharply to warm, dry grassy savanna conditions •Southwest and south coast region: increase in Ericaceae pollen (fynbos) and a decrease in *Podocarpus* pollen for the transitional period between MIS 5 and 4 at ~ 96–70 ka suggests a shift to cooler temperatures and perhaps increased rainfall seasonality; a reduction in moisture availability during MIS 4 is suggested by *Stoebe*-type pollen that is abundant at ~ 67 ka indicating rainfall seasonality and therefore marginally more arid conditions (Scott and Neumann 2018)
MIS 5a; ~ 74–84 ka; generally warm	
•Volcanic ash from the Toba eruption is present at ~ 75 ka •The lake reaches a severe low stand before ~ 76 ka, but starts to open up again from ~ 75 ka •Throughout this period the lake showed fluctuating lake, which were mostly much higher than those of the mega-droughts centred at ~ 100 and 130 ka. •The average temperature was 26.5 °C, with a range from 25.7 to 27.3 °C (Brown et al. 2007; Scholz et al. 2007; Scholz et al. 2011; Woltering et al. 2011; Lane et al. 2013)	•Interior: shows strong savanna woodland elements consisting of tree pollen belonging to *Spirostachys* and Combretaceae •Southwest and south coast region: increase in Ericaceae pollen (fynbos) and a decrease in *Podocarpus* pollen for the transitional period between MIS 5 and 4 at ~ 96–70 ka suggests a shift to cooler temperatures and perhaps increased rainfall seasonality (Scott and Neumann 2018)
MIS 5b; ~ 85–93 ka; generally cool	
•Lake levels are still at their lowest by the beginning of this period until ~ 92 ka, and remain severely low until the end of MIS5b at ~ 85 ka •The shift from leaf to grass-dominated vegetation continues to 90.6 ka •Low charcoal abundances indicate limited vegetation, and possibly a semi-desert environment in the lowland areas (Konecky et al. 2011; Scholz et al. 2011)	•South-west and south coast region: increase in Ericaceae pollen (fynbos) and a decrease in *Podocarpus* pollen for the transitional period between MIS 5 and 4 at ~ 96–70 ka suggests a shift to cooler temperatures and perhaps increased rainfall seasonality (Scott and Neumann 2018)
MIS 5c; ~ 94–106 ka; generally warm	
•This is a period of extreme drought starting at ~ 105 ka and reaching into MIS5b until ~ 90 ka •Lake levels are at its lowest throughout MIS5c •The shift from leaf to grass-dominated vegetation that started during MIS5d continues throughout this period •Low charcoal abundances indicate limited vegetation, and possibly a semi-desert environment in the lowland areas (Beuning et al. 2011; Scholz et al. 2011)	•Indian Ocean region: after ~ 105 ka, decreasing percentages of woodland pollen point to a return of glacial conditions •Southwest and south coast region: increase in Ericaceae pollen (fynbos) and a decrease in *Podocarpus* pollen for the transitional period between MIS 5 and 4 at ~ 96–70 ka suggests a shift to cooler temperatures and perhaps increased rainfall seasonality (Scott and Neumann 2018)

Table 4 (continued)

Lake Malawi as broad sub-Saharan setting	Southern African pollen record as regional variants
MIS 5d; ~ 107–113 ka; generally cool	
•MIS5d was a period of extreme drought across Africa •Throughout this period Lake Malawi shows level drawdown, with the most severe low-lake stage occurring between ~ 109 and 92 ka •The area starts to shift from leaf to grass-dominated vegetation from 111.8 ka (Beuning et al. 2011; Konecky et al. 2011; Scholz et al. 2011)	
MIS 5e; ~ 114–130 ka; generally warm	
•At the beginning of this period, the Lake Malawi region was in an extreme drought that started at 135 ka and lasted until ~ 127 ka •Lake levels are severely reduced from 135 to 124 ka •The phase between ~ 117 and 124 ka is characterised by several indicators suggesting intermediate to high lake levels and hydrologically open conditions during with water depths comparable to modern conditions •Another extreme drought started again at ~ 117 ka and would continue into MIS 5c to ~ 105 ka (Beuning et al. 2011; Scholz et al. 2011)	•Indian Ocean Region: warm conditions indicated in by high percentages of pollen of woodland/savanna taxa; forest pollen, including *Podocarpus*, is more prominent •Interior: grassy vegetation developed at Florisbad with alternating drier and wetter conditions, which cannot be well dated, but seem to extend past ~ 121 ka (Scott and Neumann 2018)

Bay points to be so long-lasting, spanning climatic changes without being much affected, its production strategies had to be accepted and transferred from generation to generation, reaching closure and stabilisation without much disruption. No analysis of possible diachronic change in Still Bay point production at Diepkloof has yet been presented. We therefore do not know what kind of techno-behavioural variation it may have contained. A pre-Still Bay phase has been reported for the site with two unifacial points that 'exhibit modification of their proximal ends through bifacial shaping', and four additional bifacial pieces are mentioned as possibly intrusive from the overlaying Still Bay layer (Porraz et al. 2013: 3383). These observations may indicate change and disruption of preceding strategies and early attempts to make Still Bay-like points at the site before their general acceptance and closure.

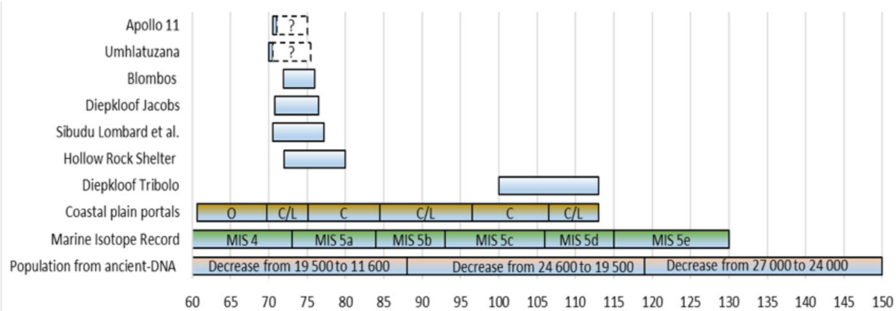

Fig. 3 Hypothetical timeline for the Still Bay set against other data used for this study (*X*-axis = thousands of years)

Across southern Africa, there are no other Still Bay sites with dates that are contemporaneous or overlap with the Tribolo set of dates for Diepkloof (Fig. 3). Thus, if this set of dates is correct, it could imply that the people at Diepkloof were so isolated that they could not share their invention with other groups on the landscape. This might have been the case towards the south if Compton's (2011) interpretation, that fluctuations in sea level isolated populations from each other, is correct. For MIS 5d, when the Tribolo Still Bay scenario started at Diepkloof, Compton's model indicates a closed/leaky situation that changes to closed during MIS 5c. This hypothesis, however, cannot explain why the innovation did not spread within the western coastal plain region. Such a localised technological tradition more likely indicates that if other groups were around, they rejected the idea of Still Bay point production at the time so that it never reached closure and stabilisation beyond Diepkloof. Genetic data indicate that for the period spanning the Tribolo Still Bay scenario there was a decline in population size from 24,600 during the end of MIS 5e (~ 118.9 ka) to 19,500 by the middle of MIS 5b (88.5 ka) (Fig. 3).

After people stopped Still Bay point production at Diepkloof by 100 ± 8 ka (Tribolo scenario, Table 3), the current archaeological record indicates that no one made similar artefacts anywhere else for another 20,000 years (Fig. 3). Similar to some other sites, the Still Bay at Diepkloof was followed by the Howiesons Poort techno-complex (Lombard et al. 2012; Porraz et al. 2013), which usually do not include bifacial point production as a key formal feature (but see de la Peña et al. 2013; de la Peña and Wadley 2014; de la Peña 2015). The Howiesons Poort represents a technical reorganisation (de la Peña 2015; Lombard et al. 2019), which according to the set of dates used for the Diepkloof Tribolo scenario could have happened during the first half of MIS 5 at ~ 90 ka (Tribolo et al. 2013). The appearance of the Howiesons Poort signifies a destabilisation that resulted in the end of Still Bay point production at the site. A few bifacial pieces reminiscent of the Still Bay were found in the basal Howiesons Poort layers (Porraz et al. 2013), which might be a result of mixing, but could also indicate that the destabilisation of the Still Bay was not an abrupt event (also see Lombard et al. 2019).

Building on the Tribolo dating scenario (Table 3; Fig 3), and if the points described for Diepkloof were indeed Still Bay points and not part of a different techno-complex, a reinvention of Still Bay point-production technology seems to have happened at Hollow Rock Shelter by 80 ± 5 ka (Högberg 2014). It is difficult, however, to explain how such a specific way of point production (see Högberg and Lombard 2016a; Lombard and Högberg 2018) could make the 20,000-year leap between Diepkloof and Hollow Rock Shelter that are roughly about 80 km from each other without any spatiotemporal evidence of cultural transmission (Fig. 2).

An alternative is the Jacobs set of dates for Diepkloof (Table 3) where the Still Bay at Hollow Rock Shelter could represent its oldest known introduction, starting well into MIS 5a (Table 4). Subsequently, the technology stabilised as it became the dominant formally, retouched tool class made/used at the site and was brought to closure by transferring the knowledge from generation to generation (see Högberg and Larsson 2011; Riede et al. 2018), over a period that could have stretched up to eight millennia into the middle of MIS 4 until 72 ± 4 ka (Fig. 3). There was no occupation at Hollow Rock Shelter after its Still Bay phase (Högberg 2014), so that the people who used to live there might have relocated, perhaps with their technical knowledge. The Compton model suggests that for the period between 84.5 (86–83) and 75.1 (77–72) ka, the route between the coastal plains was closed, which may have prevented the spread of Still Bay point making towards the south. There are no obvious climatic events recorded from the Lake Malawi core at ~ 80 ka when the Still Bay started at Hollow Rock Shelter, but MIS 5a seems to have been a period during which the climate generally improved after the severe droughts of the previous sub-stages. Based on the local pollen record, Scott and Neumann (2018) suggest a shift to cooler temperatures, an increase in the current characteristic 'fynbos' taxa of the southern Cape, and possibly increased rainfall seasonality at ~ 96–70 ka (Table 4). This could mean that the landscape slowly opened up for people and their ideas to spread as a result of shrinking arid zones or semi-desert conditions, an interpretation partly supported by the sea-level fluctuation that indicates closed/leaky conditions towards the southern Cape for the period between 75.1 (77–72) and 69.7 (71.5–67.5) ka (Compton 2011).

It is then also during MIS 5a, despite a continued drop in the hunter-gatherer population size (Schlebusch et al. 2017), and only a few millennia after the first Still Bay points appear at Hollow Rock Shelter, that we see people start making them at other places. At Sibudu in KwaZulu-Natal Still Bay points appear by 77.2 ± 2.6 ka during its pre-Still Bay phase (Lombard et al. 2019), at Diepkloof at 76.5 ± 3.3 (Jacobs scenario), and at Blombos on the south coast by 76.0 ± 3.8 ka (Table 3). The early appearance of Still Bay points at Sibudu may well reflect that contact with groups towards the northeast were not similarly affected by fluctuations in sea level as those towards the south, but this assumption remains to be assessed.

For Blombos Cave there is a series of ages for the Still Bay indicating a duration of at least 4000 years before the site was vacated after 71.9 ± 3.7 ka and the deposit sealed with a sterile sand layer (Jacobs and Roberts 2017). In the context of the only diachronic work thus far on the assemblage, Archer et al. (2015) suggested that throughout the techno-complex's duration at the site it seems that bifacially shaped Still Bay points became increasingly elongated and standardised, which may be an indication of technological stabilisation or of societal changes and subsequent stabilisation in associated pedagogical methods that resulted in the standardisation observed archaeologically. Either interpretation is relevant within the socio-technical framework as it incorporates all types of interplay between society and technology.

In this scenario, the seemingly rapid (in Middle Stone Age terms) spread of the Still Bay between ~ 77 and 76 ka to the south and northeast across diverse biomes could imply that groups who came in contact started to copy each other's way of making retouched points. Thus far, there is no evidence that people exchanged the points themselves over long distances (different from the arrows of more recent hunter-gatherer groups in the region, see e.g. Wiessner 1983), as the majority of points from each site were made on stone materials available within a day's walking distance. The fact that distinct Still Bay-type points, with little or no significant morphometric variability (e.g. Lombard and Högberg 2018; Lombard et al. 2019; but see Archer et al. 2016), are present at several sites at roughly the same time, however, implies less variation and flexibility in point production and/or in the way knowledge about how to make a retouched point was socially transmitted among peers from different groups (also see Mackay et al. 2014). In the context of a socio-technical framework, this would reflect widespread closure and stabilisation of Still Bay point production and that it probably became an institutionalised, socially transmitted tradition before the onset of MIS 4.

Thus, apart from the Diepkloof Tribolo scenario that might link the beginning of Still Bay point production at that site with an extreme drought and possibly semi-desert conditions, it seems that ecological conditions were probably not the main reason for the inception and spatiotemporal spread of Still Bay points (see Jacobs et al. 2008 for similar interpretation). Instead, we argue that their general social acceptance by different groups across the landscape may have benefitted from the ameliorating circumstances experienced during MIS 5a that continued into MIS 4 (Table 4), despite the drop in population size reaching its lowest point of ~ 11 600 at 58.9 ka (Fig. 3; and see Schlebusch et al. 2017, Fig. S18 for reconstructed population sizes). The Lake Malawi core associated with MIS 4 further shows an increase of evergreen woodlands and higher water levels compared to the previous stages in that region, although it was relatively cold (Table 4), and from 69.7 (71.5–67.5) ka the route between the coastal plains was probably open for the movement of people and animals (Compton 2011). The South African pollen record shows variation between regions in MIS 4, with the Indian Ocean and interior regions having rather dry conditions and the southwest and south coast region marginally more arid conditions (Table 4).

From the available dates, it would seem that it took another few thousand years before the appearance of Still Bay points at Umhlatuzana Rock Shelter at 70.5 ± 4.7 ka (Table 3; Fig 2). However, this is currently the only date and was retrieved from the uppermost Still Bay level at the site (Lombard et al. 2010). We may therefore accept that people started to make Still Bay points before this, but we cannot yet determine the time depth of the techno-complex at the site (Fig. 3). We know that some Still Bay points at Umhlatuzana were made differently than elsewhere in that they were pressure flaked with finely serrated edges without being morphometrically different from other Still Bay points (Lombard et al. 2010; Högberg and Lombard 2016ab; Lombard and Högberg 2018). This could reflect a localised stylistic expression in which the typical Still Bay shapes were copied and a new element added to distinguish points made at Umhlatuzana from those, for example, made at the relatively nearby site of Sibudu. Denticulated/serrated points are, however, present in the older than ~ 77 ka layers at Sibudu (Rots et al. 2017), so that it is possible that the original idea spread from that site, was subsequently discontinued there (Lombard et al. 2019), but copied and brought to closure at Umhlatuzana. Thus far, it seems that this way of making Still Bay points, however, never reached broad, supra-regional closure and stabilisation. Instead, it remained a localised or regional way of point production, similar to heat treatment that was applied at sites where the raw material was conducive of such techno-behaviours (Brown et al. 2009; Schmidt and Högberg 2018). The Still Bay at Umhlatuzana also stands out in terms of the use of blades as blanks to produce points from, a techno-behaviour thus far only recorded at this site (see Högberg and Lombard 2016a; Lombard and Högberg 2018; Lombard et al. 2019). This may reflect a further local development that reached acceptance and stabilisation only at this site, and like the serrated points, this point-production strategy seems not to have reached broad socio-technical closure beyond the people living at Umhlatuzana.

The Still Bay expression at Apollo 11 Rock Shelter in southern Namibia also has only a single date that was first published as 71 ± 3 ka (Vogelsang et al. 2010) and recently re-worked to 70 ± 2.9 ka (Jacobs and Roberts 2017) (Table 3). Similar to Sibudu, Diepkloof and Umhlatuzana, the Still Bay at Apollo 11 is overlain by the Howiesons Poort techno-complex with an age estimate of 63 ± 2 ka, from which it is separated by a thin sterile layer dating to 67 ± 3 ka (Vogelsang et al. 2010). Whereas there is considerable deposit below the one published for the Still Bay, there are no age estimates available for these occupations so that it is not possible to speculate about the duration of the techno-complex at the site (Fig. 3) or about variation on point production through time. We have found, however, that morphometrically, the Apollo 11 points are almost identical to those of the Umhlatuzana assemblage and very similar to those from Hollow Rock Shelter (Lombard and Högberg 2018). At Apollo 11, however, we found relatively more unifacial points in the Still Bay assemblage compared to other sites (Lombard and Högberg 2018; Lombard et al. 2019). This may be a local/regional socio-technical development of the Still Bay in this northern-most inland locality. Unifacial point production, although often neglected as part of the Still Bay, is one of five strategies we previously identified associated with Still Bay point assemblages (see Högberg and Lombard 2016a; Lombard and Högberg 2018 for details to the approach). We found that people used at least four out of the five strategies at sites such as Hollow Rock Shelter, Sibudu and Umhlatuzana, but only two at Apollo 11 (we note, however, that due to not having access to the material, similar analyses have not been completed on the assemblages from Diepkloof or Blombos). It is therefore likely that by the time the 'idea' of making Still Bay points was introduced at Apollo 11, only two point-production strategies were taken up by its inhabitants with the unifacial point-production strategy reaching a local/regional stabilisation as the most commonly used.

We found, however, that a single production strategy (the bifacial nodule point-production strategy 1, see Högberg and Lombard 2016a; Lombard and Högberg 2018 for definition) seems to have been used at all the sites, including Blombos and Diepkloof (Villa et al. 2009; Porraz et al. 2013; Lombard and Högberg 2018). This observation suggests a supra-regional stabilisation of 'how to make Still Bay points' (technologically and/or pedagogically)—a shared convention for Still Bay point production over and above any variations across space or through time. As mentioned, points were made of local raw materials, and although at each site specific point-production strategies correlate to some extent with material availability (Högberg and Lombard 2016a; Lombard and Högberg 2018), we do not see a correlation between raw material and point-production strategies on a supra-regional scale (Lombard et al. 2019).

Thus far, we only have fine-grained, diachronic/vertical data for variation in Still Bay point production from one site, Sibudu Cave. Here, we analysed all the points and point fragments from six stratigraphic contexts: (1) Wadley's earlier pre-Still Bay layers thus far undated; (2) Wadley's later pre-Still Bay layers with the uppermost layer dated to 77.3 ± 2.7 ka; (3) a potential hiatus in point production dated to 73.2 ± 2.7 ka; (4) earlier Still Bay layers dated to 72.5 ± 2.5 ka; (5) a later Still Bay layer dated to 70.5 ± 2.4 ka; and (6) the terminal Still Bay/Wadley's early Howiesons Poort dated to 64.7 ± 2.3 ka (Lombard et al. 2019). Figure 4 shows variation in the frequency of the bifacial nodule point-production strategy 1 at Sibudu through time (the dark grey bar towards the left of the chart). Looking at that point-production strategy as 'gold standard' (see Villa et al. 2009) for the Still Bay through a socio-technical lens, we may infer the following:

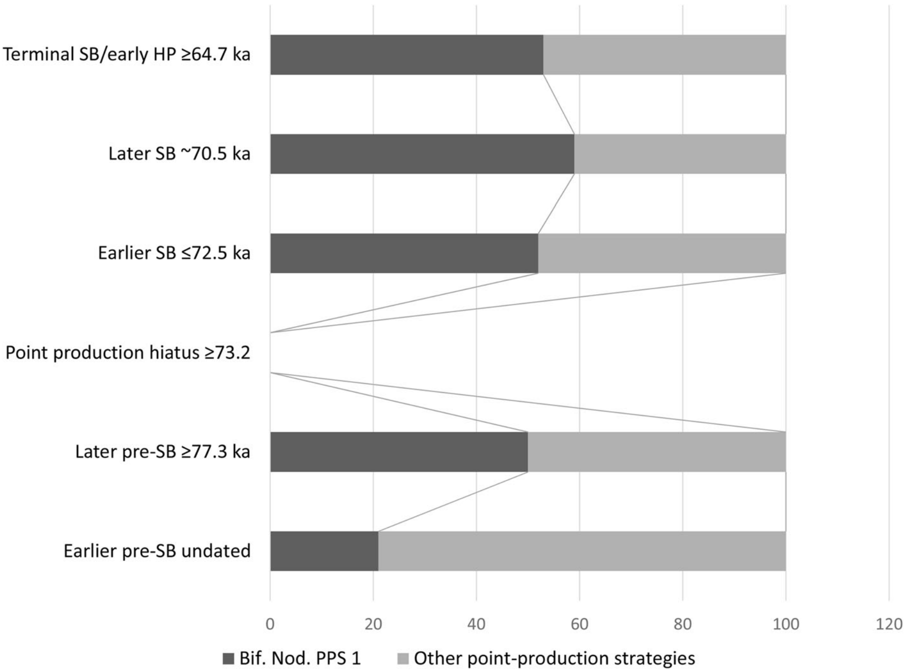

Fig. 4 Variation in bifacial nodule point-production strategy 1 and other point-production strategy frequencies at Sibudu Cave through time (adapted from Lombard et al. 2019)

1. At the time this particular way of making points were introduced at the site, sometime before ~ 77 ka, people were still making most (89 %) of their points in a different manner indicating that closure has not yet been reached.
2. By ~ 77 ka, however, 50% of all points were made in this manner, indicating a marked raise in acceptance and potential closure.
3. A possible point production hiatus is indicated at ~ 73 ka. This may be seen as technological destabilisation, but could also indicate variability in site use or spatial organisation at the site (for further discussion about this phenomenon see Lombard et al. 2019).
4. During the earlier Still Bay phase at Sibudu (~ 72.5 ka), we already see 52% of all points were made according to the Still Bay 'gold standard', indicating that this way of point production was widely accepted within the group that lived there. Depending on how the earlier possible hiatus in point production is understood, this might be interpreted as an indication of a new closure, alternatively as a sign of stabilisation.
5. By ~ 70 ka during its later phase, most points (59%) were made using the bifacial nodule point-production strategy 1. We suggest that this indicates stabilisation of the Still Bay at the site.
6. By the time that the Howiesons Poort techno-complex is introduced at Sibudu by ~ 65 ka, the bifacial nodule point-production strategy 1 way of making points starts to diminish, or may be present only as a result of mixing with older deposit (see Lombard et al. 2019 for discussion). In the subsequent layers, it disappears completely—a clear indicator of socio-technical destabilisation and at the same time an introduction of something new.

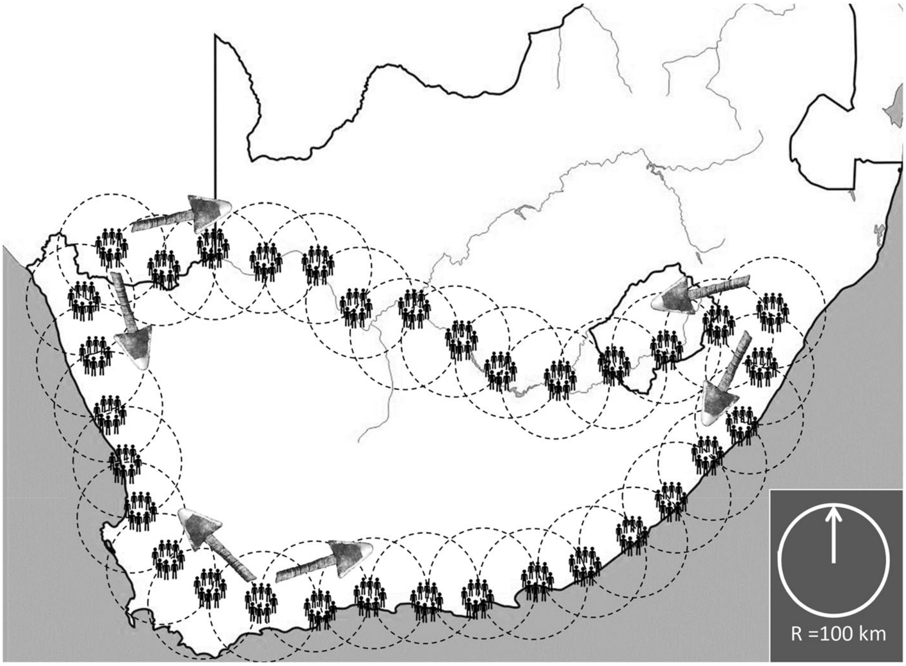

Fig. 5 Based on the ethno-historical record, southern African hunter-gatherers of the Holocene had social networks that reached up to ~ 100 km in each direction. Within this system, a particular arrow could hypothetically be passed on from group to group within less than 15 years over a distance of ~ 1500 km from east to west across the subcontinent, or from north to south, and vice versa, without the people themselves travelling this distance. This map is a hypothetical illustration of such a system that could have functioned along the coastline and major river systems of South Africa

Returning to the horizontal/geospatial perspective, it seems that by or shortly after ~ 70 ka, people either moved away from some sites (such as Blombos) or that they stopped producing Still Bay points (Table 3; Fig 3). At Diepkloof, Sibudu, Umhlatuzana and Apollo 11, people started to use knapping conventions associated with the Howiesons Poort. Early Howiesons Poort layers often contain Still Bay points, but it is not yet certain whether this is a result of mixing or a transitional effect (Kaplan 1990; Wadley 2007; Porraz et al. 2013; Lombard et al. 2019). Either way, the transition to the Howiesons Poort techno-complex signals a socio-technical destabilisation on local, regional and supra-regional levels and the ultimate demise of the Still Bay across southern Africa by the first half of MIS 4, when the data from the Lake Malawi core indicate more humid conditions with rising water levels and lowering temperatures, also indicated by the South African pollen record (Table 4).

To conclude, observed through a socio-technical lens, at the time of Still Bay point production, society in southern Africa was organised in a way that facilitated the transmission of knowledge and ideas across generations and vast landscapes. In the south, technological expansion might have been temporarily affected by variation in sea levels, but by around 76 ka Still Bay point production reached broad closure and stabilisation over large areas. Based on previous models of conditions for intra-generational skill transmission in relation to population size (e.g. Henrich 2004, but see d'Errico and Banks 2013; Vaesen et al. 2016 for discussion), a reasonable hypothesis would be that a decrease in population size would affect the spatiotemporal spread of technological innovations negatively, yet we do not see such correlations from our multi-data set socio-technical scenarios. Instead, we see a broadly contemporary drop in population size together with an expansion of the Still Bay point production over large areas. Agent-based modelling, for example, has shown that more frequent base-camp moves could be correlated with higher inter-group interactivity (Premo 2012). Such increased residential mobility could explain how a smaller population may be able to interact across a larger landscape.

Concluding Discussion

Here, we illustrated the socio-technical framework using modern examples of bicycles, tyres and electric guitars and historical as well as prehistoric examples of Australian Kimberly points and southern African Middle Stone Age Still Bay points. In the modern examples, the socio-technological frameworks are relatively clear. It is possible to unfold in detail how technologies vary and how processes of introduction, closure, stabilisation, destabilisation and copying works. As we move further back in time, however, processes become increasingly blurred, many details impossible to uncover and discussion consequently becomes more speculative.

A confounding aspect for instance is that the historical examples (bicycles, tyres and electric guitars) represent contexts of craft specialisation in which the producers of the material culture are far removed from the end users. Thus, in modern technologies, the layered participation, opinions and positions of power represented by people such as designers, engineers, craftsmen, sales personnel, buyers and end users may all impact on what ultimately becomes accepted by society. In the case of the bicycle, for example, Pinch and Bijker (1984) also make the point that the changing social negotiation around the attractiveness of the ordinary, as opposed to the safety bicycle (with their different tyres), was a result of the differential power of certain groups of actors over others—namely the influential opinions of young male purchasers/users trumping the influence of less powerful users, old men and women of all ages—in the eyes of the designers who decided what got made. Of course, Stone Age/Palaeolithic societies such as those who manufactured what we call Still Bay points today would not have had such separation between producers and the users. Thus, it can be expected that even if ideas about how to make a point were exchanged over long distances, those who transferred the knowledge were probably also making the points. Power dynamics impacting on a decision-maker's perspective about adopting or rejecting a new knapping behaviour were therefore less layered compared to modern examples, resulting in a more insulated social process.

We have shown, however, that despite gaps—in our knowledge, in the archaeological record, in dating or in our understanding of the complexities inherent in knowledge transfer systems at work within and between groups—the socio-technical approach allows for hypothesising about prehistoric dynamics associated with specific lithic technologies. We do not know the specific contexts of deep-time hunter-gatherer knowledge transfer systems or how they worked (e.g. Högberg and Lombard 2016a). Yet, it is reasonable to assume combinations of intra- and inter-generational transfer of knowledge through social learning, teaching and play-copying, conducted in a range of alternatives (e.g. from a one-on-one basis to a many-to-many context as well as horizontally distributed within a generation and/or vertically between generations), and in various social settings (Eerkens and Lipo 2007; d'Errico and Banks 2015; Lombard and Högberg 2018; Riede et al. 2018).

Similar to Australian hunter-gatherer communities, the San hunter-gatherers of southern Africa left a rich ethno-historical record regarding wide reciprocity exchange networks (e.g. Marshall 1976), which could have a reach of 100 km or more (Wiessner 1977, 1982). Based on certain classes of material culture, such as bone points and ostrich eggshell beads, it seems that such socio-economic structures could have existed as far back as 20,000 years ago in this region (Wadley 1987, 1989, 1993; Deacon 1990). Variation in Kalahari hunter weaponry style carried social information and formed important content in exchange networks. Wiessner (1983: 261) suggests that 'Socially, politically, and economically, San arrows have greater import than any other single San artifact. […] The arrow maker either receives a large portion of the meat or is responsible for the distribution; thus San give and lend arrows in ways that fill needs and solidify socioeconomic ties […] Arrows also have significance in boundary maintenance […] animals shot in one area may die in another, bearing the arrow of the hunter. The !Kung [a Kalahari San group] do discuss this possibility and maintain that if foreign people with different arrows are hunting nearby, eventually they would find out'. Southern African hunter-gatherer weaponry was therefore strongly associated with concepts of both individual and group identity. A quantitative approach showed that good hunters had (a) more reproductive success than poor hunters, (b) more exchange partners than poor hunters, and (c) had more adult married siblings who may assist with alloparenting than poor hunters (Wiessner 2002).

These are important fitness indicators for hunter-gatherer societies, and it is therefore reasonable to suggest that similar socio-economic configurations stretched deep into the Pleistocene. If we speculate that, based on their adaptive fitness benefits and the fact that the cogni-behavioural repertoire of the people who produced and used Still Bay points were not unlike that of more recent hunter-gatherers (e.g. Henshilwood 2012; Lombard 2012; Wadley 2015), similar social networks may have existed much earlier. If the reach of each group in such networks were roughly comparable to that of the Kalahari San (i.e. about 100 km in any one direction [Wiessner 1977, 1982]), then the idea about a new point-production strategy from Hollow Rock Shelter could have been passed on from group to group and introduced to knappers at Blombos within 5 years and Apollo 11 or Sibudu in less than 15–20 years (Fig 5).

Yet, knowledge transfer seldom happens directly or uni-directionally, sometimes, shifts in pedagogy (see Ferguson 2003, 2008 for discussion related to point production) may have happened much earlier than the actual stabilisation of a technology, and as Renfrew (2001) noted, introduced technologies might have remained untapped for some time before they came to closure (also see Hovers and Belfer-Cohen 2006). As our modern examples show, socio-technical change and persistence is not immediate, but socially negotiated. Thus, ideas about Still Bay point production probably travelled somewhat slower across the landscape and took some time to be incorporated into the technical repertoires of neighbouring groups (if and when accepted). We also know for example that some Still Bay point-production strategies reach broad supra-regional closure and stabilisation, whereas others remained a localised or regional way of point production.

Building on the example of Kimberly points, exchange networks should probably best be understood as systems of contact with a series of intermediary groups (Akerman et al. 2002) and not as groups or individuals themselves travelling long distances (Fig. 5). We suggest that seeing knowledge transfer as multi-directional and dynamic, moving back and forth between phases of introduction, closure, stabilisation, destabilisation and copying, helps to enhance our thinking about trends in lithic techno-behaviours observed in the ethno-historical and archaeological records as illustrated here by our use of Kimberley and Still Bay points.

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Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

Akazawa, T., Nishiaki, Y., & Aoki, K. (Eds.). (2013). *Dynamics of learning in Neanderthals and modern humans, cultural perspectives, volume 1*. Japan: Springer.

Akerman, K., & Bindon, P. (1995). Dentate and related stone biface points from northern Australia. *The Beagle: Records of the Museums and Art Galleries of the Northern Territory, 12*, 89–99.

Akerman, K., Fullager, R., & van Gijn, A. (2002). Weapons and wunan: production, function and exchange of Kimberley points. *Australian Aboriginal Studies, 1*, 14–42.

Archer, W., Gunz, P., van Niekerk, K. L., Henshilwood, C. S., & McPherron, S. P. (2015). Diachronic change within the Still Bay at Blombos Cave, South Africa. *PLoS One, 10*(7), e0132428.

Archer, W., Pop, C. M., Gunz, P., & McPherron, S. P. (2016). What is Still Bay? Human biogeography and bifacial point variability. *Journal of Human Evolution, 97*, 58–72.

Bader, B. D., Tribolo, C., & Conard, N. J. (2018). A return to Umbeli Belli: new insights of recent excavations and implications for the final MSA of eastern South Africa. *Journal of Archaeological Reports, 21*, 733–757.

Beuning, K. R., Zimmerman, K. A., Ivory, S. J., & Cohen, A. S. (2011). Vegetation response to glacial–interglacial climate variability near Lake Malawi in the southern African tropics. *Palaeogeography, Palaeoclimatology, Palaeoecology, 303*(1-4), 81–92.

Bijker, W. E. (1995). *Of bicycles, bakelites, and bulbs: toward a theory of sociotechnical change*. Cambridge: The MIT Press.

Bijker, W. E. (2006a). The vulnerability of technological culture. In H. Nowotny (Ed.), *Cultures of technology and the quest for innovation* (pp. 52–69). New York: Berghahn Books.

Bijker, W. E. (2006b). Why and how technology matters. In R. E. Goodin & C. Tilly (Eds.), *Oxford Handbook of contextual political analysis* (pp. 681–706). Oxford: Oxford University Press.

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (Eds.). (1987). *The social construction of technological systems. New directions in the sociology and history of technology*. Cambridge: The MIT Press.

Brown, E. T., Johnson, T. C., Scholz, C. A., Cohen, A. S., & King, J. W. (2007). Abrupt change in tropical African climate linked to the bipolar seesaw over the past 55,000 years. *Geophysical Research Letters, 34*(20), 702–707.

Brown, K. S., Marean, C. W., Herries, A. I., Jacobs, Z., Tribolo, C., Braun, D., Roberts, D. L., Meyer, M. C., & Bernatchez, J. (2009). Fire as an engineering tool of early modern humans. *Science, 325*(5942), 859–862.

Chase, B. M., & Meadows, M. E. (2007). Late Quaternary dynamics of southern Africa's winter rainfall zone. *Earth-Science Reviews, 84*(3-4), 103–138.

Chevalier, M., & Chase, B. M. (2016). Determining the drivers of long-term aridity variability: a southern African case study. *Journal of Quaternary Science, 31*(2), 143–151.

Clark, J. D. (1988). The Middle Stone Age of East Africa and the beginnings of regional identity. *Journal of World Prehistory, 2*(3), 235–305.

Clendon, M. (1999). Worora gender metaphors and Australian prehistory. *Anthropological Linguistics, 41*(3), 308–355.

Collard, M., Kemery, M., & Banks, S. (2005). Causes of toolkit variation among hunter-gatherers: a test of four competing hypotheses. *Canadian Journal of Archaeology, 29*, 1–19.

Collard, M., Vaesen, K., Cosgrove, R., & Roebroeks, W. (2016). The empirical case against the 'demographic turn' in Palaeolithic archaeology. *Philosophical Transactions of the Royal Society B, 371*(1698). https://doi.org/10.1098/rstb.2015.0242.

Compton, J. S. (2011). Pleistocene sea-level fluctuations and human evolution on the southern coastal plain of South Africa. *Quaternary Science Reviews, 30*(5-6), 506–527.

d'Errico, F., & Banks, W. E. (2013). Identifying mechanisms behind Middle Paleolithic and Middle Stone Age cultural trajectories. *Current Anthropology, 54*(S8), S371–S387.

d'Errico, F., & Banks, W. E. (2015). The archaeology of teaching: a conceptual framework. *Cambridge Archaeological Journal, 25*(4), 859–866.

de Beaune, S. A. (2004). The invention of technology—prehistory and cognition. *Current Anthropology, 45*(2), 139–162.

de la Peña, P. (2015). Refining our understanding of Howiesons Poort lithic technology: the evidence from grey rocky layer in Sibudu Cave (KwaZulu-Natal, South Africa). *PLoS ONE, 10*(12), e0143451. https://doi.org/10.1371/journal.pone.0143451.

de la Peña, P., & Wadley, L. (2014). Quartz knapping strategies in the Howiesons Poort at Sibudu (KwaZulu-Natal, South Africa). *PLoS ONE, 9*(7), e101534.

de la Peña, P., Wadley, L., & Lombard, M. (2013). Quartz bifacial points in the Howiesons Poort of Sibudu. *South African Archaeological Bulletin, 68*(198), 119–136.

Deacon, J. (1990). Weaving the fabric of Stone Age research in southern Africa. In P. Robertshaw (Ed.), *A history of African archaeology* (pp. 39–57). London: James Currey.

Dobres, M.-A. (2000). *Technology and Social Agency. Outlining a practice framework for archaeology*. Oxford: Blackwell Publishers.

Eerkens, J. W., & Lipo, C. P. (2007). Cultural transmission theory and the archaeological record: providing context to understanding variation and temporal change in material culture. *Journal of Archaeological Research, 15*, 239–274.

Feathers, J., 2015. Luminescence dating at Diepkloof Rock Shelter–new dates from single-grain quartz. *Journal of Archaeological Science, 63*, pp.164–174

Ferguson, J. R. (2003). An experimental test of the conservation of raw material in flintknapping skill acquisition. *Lithic Technology, 28*(2), 113–131.

Ferguson, J. R. (2008). The when, where, and how of novices in craft production. *Journal of Archaeological Method and Theory, 15*(1), 51–67.

Fitzhugh, B. (2001). Risk and invention in human technological evolution. *Journal of Anthropological Archaeology, 20*, 125–167.

Fullagar, R. L., Price, D. M., & Head, L. M. (1996). Early human occupation of northern Australia: archaeology and thermoluminescence dating of Jinmium rock-shelter, Northern Territory. *Antiquity, 70*(270), 751–773.

Gärdenfors, P., & Högberg, A. (2017). The archaeology of teaching and the evolution of *Homo docens*. *Current Anthropology, 58*(2), 188–201.

Geselowitz, M. N. (1993). Archaeology and the social study of technological innovation. *Science, Technology & Human Values, 18*(2), 231–246.
Giddens, A. (1984). *The Constitution of Society. Outline of the theory of structuration*. Berkeley and Los Angeles: University of California Press.
Goodwin, A. J. H., & van Riet Lowe, C. (1929). The Stone Age cultures of South Africa. *Annals. South African Museum, 27*, 1–289.
Guérin, G., Murray, A. S., Jain, M., Thomsen, K. J., & Mercier, N. (2013). How confident are we in the chronology of the transition between Howieson's Poort and Still Bay? *Journal of Human Evolution, 64*, 314–317.
Haidle, M. N. & Bräuer, J. (2011). From brainwave to tradition—how to detect innovations in tool behavior. PaleoAnthropology, Special Issue: Innovation and the Evolution of Human Behavior. pp. 144-153.
Harrison, R. (2002). Archaeology and the colonial encounter. Kimberley spearpoints, cultural identity and masculinity in the north of Australia. *Journal of Social Archaeology, 2*(3), 352–377.
Harrison, R. (2004). Kimberley points and colonial preference: new insights into the chronology of pressure flaked point forms from the southeast Kimberley, Western Australia. *Archaeology in Oceania, 39*, 1–11.
Harrison, R. (2006). An artefact of colonial desire? Kimberley points and the technologies of enchantment. *Current Anthropology, 47*(1), 63–88.
Harrison, R. (2007). Reply to Kim Akerman. On Kimberley points and the politics of enchantment. *Current Anthropology, 48*(1), 133–134.
Henrich, J. (2004). Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses: the Tasmanian case. *American Antiquity, 69*(2), 197–214.
Henshilwood, C. S. (2012). Late Pleistocene techno-traditions in southern Africa: a review of the Still Bay and Howiesons Poort, c. 75-59 ka. *Journal of World Prehistory, 25*, 205–237.
Hodacs, H., Nyberg, K., & Van Damme, S. (Eds.). (2018). *Linnaeus, natural history and the circulation of knowledge*. Oxford: Voltaire Foundation Oxford.
Högberg, A. (2009). *Lithics in the Scandinavian Late Bronze Age. Sociotechnical change and persistence*. Oxford: British Archaeological Reports International Series 1932.
Högberg, A. (2014). Chronology, stratigraphy and spatial distribution of artefacts at Hollow Rock Shelter, Cape Province, South Africa. *South African Archaeological Bulletin, 69*, 142–151.
Högberg, A., & Larsson, L. (2011). Lithic technology and behavioural modernity: new results from the Still Bay site, Hollow Rock Shelter, Western Cape Province, South Africa. *Journal of Human Evolution, 61*, 133–155.
Högberg, A., & Lombard, M. (2016a). Still Bay point-production strategies at Hollow Rock Shelter and Umhlatuzana Rock Shelter and knowledge-transfer systems in southern Africa at about 80-70 thousand years ago. *PLoS ONE, 11*(12), e0168012.
Högberg, A., & Lombard, M. (2016b). Indications of pressure flaking more than 70 thousand years ago at Umhlatuzana Rock Shelter. *South African Archaeological Bulletin, 71*, 53–59.
Hovers, E. (2009). *The lithic assemblages of Qafzeh Cave*. Oxford: Oxford University Press.
Hovers, E., & Belfer-Cohen, A. (2006). "Now you see it, now you don't": modern human behavior in the Middle Paleolithic. In E. Hovers & S. L. Kuhn (Eds.), *Transitions before the transition: evolution and stability in the Middle Paleolithic and Middle Stone Age* (pp. 295–304). New York: Springer.
Jacobs, Z., & Roberts, R. G. (2015). An improved single grain OSL chronology for the sedimentary deposits from Diepkloof Rockshelter, Western Cape, South Africa. *Journal of Archaeological Science, 63*, 175–192.
Jacobs, Z., & Roberts, R. G. (2017). Single-grain OSL chronologies for the Still Bay and Howieson's Poort industries and the transition between them: further analyses and statistical modelling. *Journal of Human Evolution, 107*, 1–13.
Jacobs, Z., Roberts, R. G., Galbraith, R. F., Deacon, H. J., Grün, R., Mackay, A., Mitchell, P. J., Vogelsang, R., & Wadley, L. (2008). Ages for the Middle Stone Age of southern Africa: implications for human behavior and dispersal. *Science, 322*, 733–735.
Kaberry, P. M. (2004 [1939]). *Aboriginal woman: sacred and profane*. London: Routledge.
Kaplan, J. (1990). The Umhlatuzana Rock Shelter sequence: 100 000 years of Stone Age history. *Southern African Humanities, 2*(11), 1–94.
Konecky, B. L., Russell, J. M., Johnson, T. C., Brown, E. T., Berke, M. A., Werne, J. P., & Huang, Y. (2011). Atmospheric circulation patterns during late Pleistocene climate changes at Lake Malawi, Africa. *Earth and Planetary Science Letters, 312*, 318–326.
Lane, C. S., Chorn, B. T., & Johnson, T. C. (2013). Ash from the Toba supereruption in Lake Malawi shows no volcanic winter in East Africa at 75 ka. *Proceedings of the National Academy of Sciences, 110*(20), 8025–8029.

Latour, B. (1992). Technology is society made durable. In J. A. Law (Ed.), *Sociology of monsters: essays on power, technology and domination* (pp. 103–130). London: Routledge.

Latour, B. (2007). *Reassembling the social. An introduction to actor-network-theory*. Oxford: Oxford University Press.

Law, J. (1992). Notes on the theory of the actor network: ordering, strategy and heterogeneity. *System Practice, 5*(4), 379–393. https://doi.org/10.1007/BF01059830.

Law, J., & Bijker, W. E. (1992). Postscript: technology, stability and social theory. In W. E. Bijker & J. Law (Eds.), *Shaping technology/building society. Studies in sociotechnical change* (pp. 290–308). Cambridge: The MIT Press.

Lemonnier, P. (Ed.). (1993). *Technological choices. Transformation in material culture since the Neolithic*. London: Routledge.

Lombard, M. (2005). Evidence of hunting and hafting during the Middle Stone Age at Sibudu Cave, KwaZulu-Natal, South Africa: a multianalytical approach. *Journal of Human Evolution, 48*(3), 279–300.

Lombard, M. (2006). First impressions of the functions and hafting technology of Still Bay pointed artefacts from Sibudu Cave. *Southern African Humanities, 18*(1), 27–41.

Lombard, M. (2007). Evidence for change in Middle Stone Age hunting behaviour at Blombos Cave: results of a macrofracture analysis. *South African Archaeological Bulletin, 62*(185), 279–300.

Lombard, M. (2012). Thinking through the Middle Stone Age of sub-Saharan Africa. *Quaternary International, 270*, 140–155.

Lombard, M., & Högberg, A. (2018). The Still Bay points of Apollo 11 Rock Shelter, Namibia: an inter-regional perspective. *Azania: Archaeological Research in Africa, 53*(3), 312–340.

Lombard, M., Wadley, L., Jacobs, Z., Mohapi, M., & Roberts, R. G. (2010). Still Bay and serrated points from Umhlatuzana Rock Shelter, KwaZulu-Natal, South Africa. *Journal of Archaeological Science, 37*, 1773–1784.

Lombard, M., Wadley, L., Deacon, J., Wurz, S., Parsons, I., Mohapi, M., Swart, J., & Mitchell, P. (2012). South African and Lesotho Stone Age sequence updated (I). *South African Archaeological Bulletin, 67*, 123–144.

Lombard, M., Jakobsson, M., & Schlebusch, C. (2018). Ancient human DNA: how the sequencing of the genome of a boy from Ballito Bay changed human history. *South African Journal of Science, 114*(1/2), 2–4.

Lombard, M., Högberg, A., & Wadley, L. (2019). Variability in point-production strategies at Sibudu from >77 000 to >65 000 years ago. *Azania: Archaeological Research in Africa, details to follow*. https://doi.org/10.1080/0067270X.2019.1619280.

MacDonald, K. (2011). Paleoanthropology, special issue: innovation and the evolution of Human behavior, introduction. pp 106-110. https://doi.org/10.4207/PA.2011.ART45

Mackay, A., Stewart, B. A., & Chase, B. M. (2014). Coalescence and fragmentation in the late Pleistocene archaeology of southernmost Africa. *Journal of Human Evolution, 72*, 26–51.

Maloney, T., O'Connor, S., & Balme, J. (2014). New dates for point technology in the Kimberley. *Archaeology in Oceania, 49*, 137–147.

Marshall, L. (1976). *The! Kung of Nyae Nyae*. Boston: Harvard University Press.

McBrearty, S. (2007). Down with the revolution. In P. Mellars, K. Boyle, O. Bar-Yosef, & C. Stringer (Eds.), *Rethinking the human revolution. New behavioural and biological perspectives on the origin and dispersal of modern humans* (pp. 133–151). Cambridge: McDonald Institute for Archaeological Research. Oxbow Books.

Meignen, L. (1998). Hayonim Cave lithic assemblages in the context of the Near Eastern Middle Paleolithic. In T. Akazawa, K. Aoki, & O. Bar-Yosef (Eds.), *Neanderthals and modern humans in Western Asia* (pp. 165–180). New York: Plenum Press.

Meskell, L., & Preucel, R. W. (Eds.). (2004). *A companion to social archaeology*. Oxford: Blackwell Publishing.

Mesoudi, A., & Aoki, K. (Eds.). (2015). *Learning strategies and cultural evolution during the Palaeolithic*. Tokyo: Springer.

Mesoudi, A., & Thornton, A. (2018). What is cumulative cultural evolution? *Proceedings of the Royal Society B, 285*(1880), 20180712.

Minichillo, T.J. (2005). Middle Stone Age lithic study, South Africa: an examination of modern human origins. PhD Thesis: University of Washington.

Mjærum, A. (2012). The bifacial arrowheads in Southeast Norway. *Acta Archaeologica, 83*, 105–143.

Mourre, V., Villa, P., & Henshilwood, C. S. (2010). Early use of pressure flaking on lithic artifacts at Blombos Cave, South Africa. *Science, 330*, 659–662.

Newman, K., & Moore, M. W. (2013). Ballistically anomalous stone projectile points in Australia. *Journal of Archaeological Science, 40*, 2614–2620.
Nowell, A. (2015). Learning to see and seeing to learn: children, communities of practice and Pleistocene visual cultures. *Cambridge Archaeological Journal, 25*(4), 889–899.
O'Brien, M. J., & Shennan, S. J. (Eds.). (2010). *Innovation in cultural systems: contributions from evolutionary anthropology*. Cambridge: MIT Press.
Parayil, G. (1991). Schumpeter on invention, innovation and technological change. *Journal of the History of Economic Thought, 13*(1), 78–89.
Pfaffenberger, B. (1992). Social anthropology of technology. *Annual Review of Anthropology, 21*, 491–516.
Pickford, M. (2004). Southern Africa: a cradle of evolution. *South African Journal of Science, 100*(3), 205–214.
Pigott, P. (1975). *Museums in Australia. Report of the Committee of Inquiry on Museums and National Collections including the Report of the Planning Committee on the Gallery of Aboriginal Australia*. Canberra: Committee of Inquiry on Museums and National Collections.
Pinch, T. J., & Bijker, W. E. (1984). The social construction of facts and artefacts: or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14*(3), 399–441. https://doi.org/10.1177/030631284014003004.
Porraz, G., Texier, P.-J., Archer, W., Piboule, M., Riguaud, J.-P., & Tribolo, C. (2013). Technological successions in the Middle Stone Age sequence of Diepkloof Rock Shelter, Western Cape, South Africa. *Journal of Archaeological Science, 40*, 3376–3400.
Premo, L. (2012). The shift to a predominantly logistical mobility strategy can inhibit rather than enhance forager interaction. *Human Ecology, 40*(4), 647–649.
Quick, L. J., Chase, B. M., Wündsch, M., Kirsten, K. L., Chevalier, M., Mäusbacher, R., Meadows, M. E., & Haberzettl, T. (2018). A high-resolution record of Holocene climate and vegetation dynamics from the southern Cape coast of South Africa: pollen and microcharcoal evidence from Eilandvlei. *Journal of Quaternary Science, 33*(5), 487–500.
Renfrew, C. (1978). The anatomy of innovation. In Social organization and settlement: contributions from anthropology, archaeology and geography. In D. Green, C. Haselgrove, & M. Spriggs (Eds.), (Vol. 47, pp. 89–117). Oxford: BAR International Series.
Renfrew, C. (2001). Commodification and institution in group-oriented and individualizing societies. *Proceedings of the British Academy, 110*, 93–118.
Riede, F., Johannsen, N. N., Högberg, A., Nowell, A., & Lombard, M. (2018). The role of play objects and object play in human cognitive evolution and innovation. *Evolutionary Anthropology, 27*(1), 46–59.
Roberts, P., Henshilwood, C. S., van Niekerk, K. L., Keene, P., Gledhill, A., Reynard, J., Badenhorst, S., & Lee-Thorp, J. (2016). Climate, environment and early human innovation: Stable isotope and faunal proxy evidence from archaeological sites (98-59 ka) in the southern Cape, South Africa. *PLoS One, 11*(7), e0157408. https://doi.org/10.1371/journal.pone.0157408.
Rots, V., Lentfer, C., Schmid, V. C., Porraz, G., & Conard, N. J. (2017). Pressure flaking to serrate bifacial points for the hunt during the MIS5 at Sibudu Cave (South Africa). *PLoS ONE, 12*(4), e0175151.
Ruttan, V. W. (1959). Usher and Schumpeter on invention, innovation and technological change. *The Quarterly Journal of Economics, 73*(4), 596–606.
Schlebusch, C. M., Malmström, H., Günther, T., Sjödin, P., Coutinho, A., Edlund, H., Munters, A. R., Vicente, M., Steyn, M., Soodyall, H., Lombard, M., & Jakobsson, M. (2017). Southern African ancient genomes estimate modern human divergence to 350,000 to 260,000 years ago. *Science, 358*(6363), 652–655.
Schmidt, P., & Högberg, A. (2018). Heat treatment in the Still Bay—a case study on Hollow Rock Shelter, South Africa. *Journal of Archaeological Science: Reports, 21*, 712–720.
Scholz, C. A., Johnson, T. C., Cohen, A. S., King, J. W., Peck, J. A., Overpeck, J. T., Talbot, M. R., Brown, E. T., Kalindekafe, L., Amoako, P. Y., & Lyons, R. P. (2007). East African megadroughts between 135 and 75 thousand years ago and bearing on early-modern human origins. *Proceedings of the National Academy of Sciences, 104*(42), 16416–16421.
Scholz, C. A., Cohen, A. S., Johnson, T. C., King, J., Talbot, M. R., & Brown, E. T. (2011). Scientific drilling in the Great Rift Valley: the 2005 Lake Malawi Scientific Drilling Project—an overview of the past 145,000 years of climate variability in Southern Hemisphere East Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology, 303*(1-4), 3–19.
Schumpeter, J. A. (1939). *Business cycles* (Vol. 1). New York: McGraw-Hill.
Scott, L., & Neumann, F. H. (2018). Pollen-interpreted palaeoenvironments associated with the Middle and Late Pleistocene peopling of Southern Africa. *Quaternary International, 495*, 169–184.
Shennan, S. (2001). Demography and cultural innovation: a model and its implications for the emergence of modern human culture. *Cambridge Archaeological Journal, 11*(1), 5–16.

Skibo, J. M., & Schiffer, B. S. (2008). *People and things: a behavioral approach to material culture*. New York: Springer Science+Business Media.

Spratt, D. A. (1989). Innovation theory made plain. In What's new? A closer look at the process of innovation. In S. E. van der Leeuw & R. Torrence (Eds.), *One World Archaeology, 14* (pp. 245–257). London: Unwin Hyman.

Sundbo, J. (1998). *The theory of innovation: enterpreneurs, technology and strategy*. Cheltenham: Edward Elgar Pub.

Taçon, P. S. C. (1991). The power of stone: symbolic aspects of stone use and tool development in Western Arnhem Land, Australia. *Antiquity, 65*, 192–207.

Thackeray, A. I., & Kelly, A. J. (1988). A technological and typological analysis of Middle Stone Age assemblages antecedent to the Howiesons Poort at Klasies River main site. *The South African Archaeological Bulletin, 43*(147), 15–26.

Tostevin, G. B. (2003). A quest for antecedents: a comparison of the terminal Middle Paleolithic and Early Upper Paleolithic of the Levant. In N. Goring-Morris & A. Belfer-Cohen (Eds.), *More than meets the eye: studies on Upper Palaeolithic diversity in the Near East* (pp. 54–67). Oxford: Oxbow Press.

Tostevin, G. B. (2012). *Seeing lithics: a middle-range theory for testing for cultural transmission in the Pleistocene*. Oakville: Oxbow.

Tribolo, C., Mercier, N., Douville, E., Joron, J. L., Reyss, J. L., Rufer, D., Cantin, N., Lefrais, Y., Miller, C. E., Porraz, G., & Parkington, J. E. (2013). OSL and TL dating of the Middle Stone Age sequence at Diepkloof Rock Shelter (South Africa): a clarification. *Journal of Archaeological Science, 40*, 3401–3411.

Vaesen, K., Collard, M., Cosgrove, R., & Roebroeks, W. (2016). Population size does not explain past changes in cultural complexity. *PNAS, 113*(16), E2241–E2247. https://doi.org/10.1073/pnas.1520288113.

Villa, P., Soressi, M., Henshilwood, C. S., & Mourre, V. (2009). The Still Bay points of Blombos Cave (South Africa). *Journal of Archaeological Science, 36*, 441–460.

Vogelsang, R., Richter, J., Jacobs, Z., Eichhorn, B., Linseele, V., & Roberts, R. G. (2010). New excavations of Middle Stone Age deposits at Apollo 11 Rockshelter, Namibia: stratigraphy, archaeology, chronology and past environments. *Journal of African Archaeology, 8*, 185–218.

Wadley, L. (1987). Later Stone Age hunters and gatherers of the southern Transvaal: social and ecological interpretation. Oxford: British Archaeological Reports International Series 25.

Wadley, L. (1989). Legacies from the Later Stone Age. *Goodwin Series of the South African Archaeological Society, 6*, 42–53.

Wadley, L. (1993). The Pleistocene Later Stone Age south of the Limpopo River. *Journal of World Prehistory, 7*(3), 243–296.

Wadley, L. (2007). Announcing a Still Bay industry at Sibudu Cave, South Africa. *Journal of Human Evolution, 52*(6), 681–689.

Wadley, L. (2015). Those marvellous millennia: the Middle Stone Age of Southern Africa. *Azania: Archaeological Research in Africa, 50*(2), 155–226.

Wiessner, P. (1977). *Hxaro: a regional system of reciprocity for reducing risk among the! Kung San* (Vol. 1). Michigan: University of Michigan.

Wiessner, P. (1982). Risk, reciprocity and social influences on !Kung San economies. In E. R. Leacock & R. B. Lee (Eds.), *Politics and history in band societies* (pp. 61–84). Cambridge: Cambridge University Press.

Wiessner, P. (1983). Style and social information in Kalahari San projectile points. *American Antiquity, 48*(2), 253–276.

Wiessner, P. (2002). Hunting, healing, and hxaro exchange: a long-term perspective on !Kung (Ju/'hoansi) large-game hunting. *Evolution and Human Behavior, 23*(6), 407–436.

Wobst, H. M. (1977). Stylistic behavior and information exchange. *Michigan Anthropological Papers, 61*, 317–342.

Woltering, M., Johnson, T. C., Werne, J. P., Schouten, S., & Damsté, J. S. S. (2011). Late Pleistocene temperature history of Southeast Africa: a TEX86 temperature record from Lake Malawi. *Palaeogeography, Palaeoclimatology, Palaeoecology, 303*(1-4), 93–102.

Ziegler, M., Simon, M. H., Hall, I. R., Barker, S., Stringer, C., & Zahn, R. (2013). Development of Middle Stone Age innovation linked to rapid climate change. *Nature Communications, 4*, 1905. https://doi.org/10.1038/ncomms2897.