Resilience and reversibility: Engaging with archaeological record formation to inform on past resilience

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1. Resilience in the archaeological record

In the age of global human-induced climate change, the vulnerabilities of coupled human and natural systems have come into clearer focus. Resilience has gained currency as a property of contemporary socio-ecological systems (SES) and a framework which describes how adaptive management of systems can buffer against disturbances (Scheffer 2009). Resilience is variably defined, but, in SES, typically refers to the capacity for a system to withstand or adapt to change while maintaining its core functions (Holling 1973). This is often conceptualized in terms of a 'stability landscape': a system in dynamic equilibrium that orbits within a basin of attraction, so that if the system is pushed away from the equilibrium by disturbances, counteracting forces will return the system to its equilibrium state (Scheffer 2009; Walker et al. 2004). However, some systems may have more than one basin of attraction and certain forces, internal or external, can push these systems into an alternative basin, forcing a reorganisation of components (fig. 1). Increasing resilience, then, is accomplished by either widening the preferred basin of attraction to include a broader range of states (termed 'latitude', shown as the basin width in fig. 1), or altering the probability of transitioning between basins by withstanding greater degrees of disturbance (termed 'resistance', shown as the basin depth in fig. 1). These fundamental concepts offer a flexible framework for describing the stability and/or vulnerability of systems and the drivers of change within them.

Resilience frameworks have found applicability in studies of the deep human past (e.g., Redman 2005; Riel-Salvatore and Negrino 2018; Stiner and Kuhn 2006; Stiner et al. 2000), and it is argued that historical sciences provide the means to understand longer-term processes that influence the resilience of present-day systems (van der Leeuw and Redman 2002). However, these frameworks are operationalised in different ways (Bradtmöller et al. 2017). Some studies focus on resilience as a property of past systems seen through the archaeological record, frequently, through human responses to disasters such as floods, volcanic eruptions, or other catastrophic shocks that are likely to push the adaptive capacity of SES to an extreme (e.g. Sheets 2012; Torrence 2016). Alternatively, other studies emphasise how continuity and change are both necessary in the maintenance of SES (e.g., Redman and Kinzig 2003; Solich and Bradtmöller 2017), a condition illustrated by the so-called adaptive cycle: a cyclical model of systemic change characterised by phases of growth (r), conservation (K), release (Ω), and reorganisation (α) (Gunderson and Holling 2002).

No matter the approach, operationalisation of resilience as a means to understand the past depends on associations between records of human activity and the resilience or adaptive phases of SES. Differential preservation of the archaeological record is a perennial concern (Perreault 2019). The record is not a complete archive of human activity but a collection of mostly unintended material residues that vary in durability and are visible in the geological matrix. However, beyond these concerns, there are different ways through which material culture might interface with the processes that contribute to resilience, that have implications for their patterning in the record. In a straightforward scenario, humans might actively use technology to influence the resistance or latitude of a basin, and the evidence of that technology changes in concert with the intensity of the disturbance. Alternatively, changes in behaviour that contribute to resilience may occur, which leave little trace but allow other elements of material culture to persist. In other words, factors contributing to the resilience of a system may not align directly with material expressions of past human activity.

The visibility of such alignments may depend not only on the preservation of the archaeological record, but on the nature of the change itself. Feedbacks of substantial amplitudes might be expected to shift archaeological patterning directionally. By this same token, small-scale changes employed strategically to increase overall resilience may leave a less coherent pattern in the wake of continuity. Lucas (2008: 63, 2012) suggests that some material patterns are reversible while others are less so. He contrasts examples of reordering a bookshelf, which is easy to accomplish and leaves little or no sign of the original order, with changing left- or right-handed traffic systems, which requires increasing effort to modify as time goes on. Patterns of material organisation that are reinforced by what occurred in the past are less easily reorganised, reflecting longer-term, persistent trends. In contrast, activities that frequently change in terms of their depositional outcomes are less likely to leave discernible patterns in the record. As a result, the most irreversible patterning would be that which leaves durable material traces and, like the traffic system, is reinforced in each act of inscription by the system to which it contributes.

Following this, patterns in the record may be differently reversible depending on their role in maintaining resilience or as systemic components retained by that resilience (see also Bailey 1983, 2007). Therefore, it is important that associations between resilience and patterning of the archaeological record not be assumed, but that interactions between them be investigated. The archaeological record is organised according to relationships (e.g. social, ecological, taphonomic) in both time and space, exhibiting emergent qualities that are not captured by a study of proximal causes alone (Dibble et al. 2017; Rezek et al. 2020). Evaluating variability in these records requires knowing how these relationships influence archaeological patterning. However, the spatial, temporal, and organisational scales at which these processes occur makes direct experimentation with the relevant social and ecological parameters prohibitive.

Formal models, such as computer simulations, can evaluate analogous processes that inform on historical systems (Barceló and Del Castillo 2016; Costopoulos and Lake 2010; Kohler 2000; Lake 2015; Romanowska et al. 2019; Wurzer et al. 2015). If a model faithfully represents the 'verbal logic' (Servedio et al. 2014) of a process or system presumed to have operated in the past (that is, how the archaeologist thinks it may have occurred or operated), it can function as a virtual laboratory where that logic can be experimented with and outcomes compared (Epstein 2008; Gilbert and Troitzsch 2005). The goal is not to replicate historical events but to explore possible scenarios which may influence patterns like those observed in the archaeological record (Davies 2018; Perry et al. 2016; Premo 2010). Observed data can be contextualised within the range of simulated outcomes, giving theoretical insight into possible generative mechanisms.

Here, we draw on a case study from semi-arid Australia to demonstrate how resilience can be operationalised using models of archaeological formation. Stone artefact scatters are a common archaeological residue in the region that reflect their users' mobility. In forager societies, changes in mobility are considered representative of different phases in the adaptive cycle, and patterning in artefact density is used to show this. We examine the formation of patterning in the Australian case study using an explicit model that aims to demonstrate differences in mobility and occupation, comparing empirically recorded patterns to different model outcomes. The implications are then considered in terms of resilience and its archaeological visibility.

2. Rutherfords Creek

Rutherfords Creek is a 13 km long stream catchment in western New South Wales (fig. 2). The land around the creek catchment is mostly flat, under 250 m elevation, and bounded by low hills on the western flank of the ephemeral Peery Lake. Irregular local storms can produce, depending on their magnitude, standing water in the lake and pools along ephemeral creeks for periods up to a few years. The lake is also part of a system of overflow basins associated with the Paroo River, and flooding in that system can fill the lake (but not the creeks) even in the absence of local rainfall.

Local temperatures fluctuate seasonally, with hot summers and mild to cool winters. The average annual rainfall is approximately 245 mm, with pan evaporation typically exceeding precipitation. However, rainfall is erratic on a month-to-month or year-to-year basis. Droughts are recurrent, with increasing incidence related to the El Niño-Southern Oscillation (Marx et al. 2009). At the same time, low latitude exposure to monsoon troughs can lead to flooding (Bell 1979). These factors contribute to high temporal and spatial variation in natural resources availability and predictability.

Defining features of the landscape are the ‘scalds’: indurated subsurface sediments exposed through wind and water erosion featuring lagged archaeological deposits on the surface. These exposures range in size from 10 m^2 to more than 5000 m^2 and cover more than 13% of the valley floor. Dating of underlying sediments and surface combustion features (heat retainer hearths or fireplaces) places most assemblages within the last 2000 years (Fanning et al. 2009). Experimental and field data suggest that erosive forces operating on surface sediments have a negligible impact on the lateral position of clasts larger than 20 mm (Fanning and Holdaway 2001). The result is a highly visible record of the distribution of artefacts accumulated over the late Holocene.

Surveys conducted on 93 scalds along the length of Rutherfords Creek recorded a total of 25,338 stone artefacts (Holdaway et al. 2012), with assemblage densities that vary over several orders of magnitude (0.003/m^2 - 11.4/m^2). Varying densities of artefact assemblages across landscapes have been argued to indicate differential occupation intensity (Moncel and Rivals 2011; Neme and Gil 2009; Veth 1993; Williams 1998). Previous work has also demonstrated that higher density in assemblages at Rutherfords Creek correlates positively with assemblage diversity (Davies and Holdaway 2017); such patterning is consistent with a shift toward decreased mobility and higher populations in arid Australia more generally (Smith 2013).

In a recent consideration of resilience among forager societies, Solich and Bradtmöller (2017) provide a typology of social systems in various states of the adaptive cycle. The typology is based on the notion of ‘connectedness’, reflecting social complexity and juxtaposed with flexibility. The connectedness of social groups is described by characteristics such as diet specialisation, social relationships, and mobility, which in turn are identified by a host of archaeological proxies. For example, patterns in the relative densities and diversities of artefact assemblages found in sites associated with European Upper Palaeolithic (UP) technocomplexes are used as evidence of varying configurations of mobility and site occupation, which align with more or less flexible forms of social organisation. By connecting patterns like artefact densities observed at different time periods to different ‘types’ of societies exemplified in part by varying mobility and occupation intensity, Solich and Bradtmöller (2017) suggest that the succession of UP technocomplexes map on to adaptive cycles, providing insights into the dynamics of past societies.

Do the archaeological patterns observed at Rutherfords Creek likewise reflect a connected/complex social system? We address this question by modelling how different mobility configurations combine to produce variation in artefact density and how density co-varies with another measure of mobility: the Cortex Ratio. First, we discuss general relationships between mobility and the accumulation of archaeological residues. Next, we introduce a model capable of simulating different mobility configurations and their effects on the Cortex Ratio. We then use an agent-based simulation to demonstrate how this measure is sensitive to differences in occupation intensity versus repeated accumulation. Finally, we compare assemblage values from Rutherfords Creek with simulation outcomes, illustrating the importance of considering the coupling between archaeological patterning and resilience.

3. Modelling the record as an emergent outcome of mobility configurations

Mobility is a primary mechanism by which organisms manage their resilience. Movements to find resources and avoid hazards can enhance resistance against disturbances, such as resource depletion and natural disasters (Nathan et al. 2008). Changes in human mobility are strongly linked with environmental and population dynamics, and transitions between mobility configurations are frequently associated with shifts in subsistence practices and social organisation (Binford 1978; Boyd 2006; Close 2000; Holdaway et al. 2010; Kelly 1992; Rafferty 1985). Changes in mobility often feature as part of human evolutionary narratives (Bar-Yosef and Belfer-Cohen 1992; Kuhn et al. 2016).

The role of mobility in the formation of assemblage densities can be conceived using 'tortuosity' of movement and the 'frequency' of occupation within a window of observation (Davies 2016; Douglass 2010) (fig. 3). Tortuosity refers to the number of redundant moves occurring during an occupation episode of a given space, while frequency refers to how often occupation occurs at that space. In this case, the windows of observation are the surveyed scalds. Differences in assemblage densities might arise from different tortuosity of movement from place to place (fig. 3A); for example, one place being used as a long-term camp (numerous redundant movements) while another used for short-term resource extraction (less redundant movements). Alternatively, densities might vary due to different frequencies of similar types of movements; for example, two places visited with different frequencies by groups performing more or less the same activities at both (fig. 3B). Conceived in this way, movements that vary in terms of tortuosity or frequency have the capacity to produce differences in artefact densities between assemblages. However, they reflect different kinds of connections with the land, with ramifications for interpretations of past resilience.

To model variability within these relationships, we utilised a generative, agent-based simulation. In our simulation, agents represent human beings that collect raw stone from their local environment, reduce it to produce cortex-bearing flakes and cores, and then carry flakes and/or cores with them along a movement path, discarding them at each stop within a window of observation. Rather than simulate the totality of movements, many having no archaeologically visible outcome, this model considers movements as linear displacements between discard events. Therefore, it is an assumption of the model that lithic procurement and discard behaviour is embedded to some extent in a wider pattern of movement. It is also assumed that raw material is available throughout the simulated environment, allowing agents to replenish stone implements as needed. While the spatial availability of raw material may be more constrained in other cases, the ubiquity of highquality silcrete (an isotropic stone formed through the cementation of soils and dissolved silica) around Rutherfords Creek from outcrops, stony desert pavements, and dry creek beds makes this assumption unproblematic for this study (Douglass and Holdaway 2011). Below we provide some general details about the simulation (code and metadata are available at https://doi.org/10.5281/zenodo.4441289).

3.1. Modelling stones

Stones are geometric solids with qualities such as surface area and volume that are also transferred to their products when flaked. For example, as stone is worked through reduction to make implements, the cortex (surface area) of the parent core is transferred to flakes (fig. 4). The collective cortex from a single reduction event could remain in proximity to the location where reduction occurred or be dispersed through movement.

If the average surface area of raw material can be estimated (Holdaway and Douglass 2015; Lin et al. 2010), a comparison can be made between how much cortex is present and how much should be expected given the amount of material in an assemblage. This is called the Cortex Ratio (Dibble et al. 2005). Values deviating from 1 indicate that cortex-bearing objects were selected and moved in or out of the assemblages (Douglass et al. 2008). By using the geometric properties of stone to show the separation of reduction components, the Cortex Ratio provides a relative measure of mobility that can be widely applied across stone technologies (e.g. Ditchfield et al. 2014; Lin et al. 2016; Phillipps 2012; Phillipps and Holdaway 2016; Reeves 2019).

Variability in the shape of raw material and reduction products has influence over assemblage-level Cortex Ratios (e.g., Dibble et al. 2005; Douglass and Holdaway 2011; Parker 2012), however it is useful to simplify these relationships for the sake of model clarity. In this simulation, raw stone nodules are modelled as icosahedra (fig. 5). Each face, representing 5% of the original nodule's surface area, can be removed as a flake and considered a separate object with an arbitrary but constant percentage of original nodule volume (1%). Nodules in the model that have flakes removed become cores, with attributes reflecting the percentage of surface area and volume remaining. Non-cortical flakes are not considered here to simplify the model and emphasise the impact of movement processes on model outcomes. While non-cortical flakes form a component of archaeological assemblages, including those at Rutherfords Creek, they represent a small percentage of the volume of a modelled reduction set and none of its original surface area. Heavily targeted selection and transport of non-cortical flakes would be required to influence Cortex Ratios.

A 'reduction' parameter controls the extent to which any core is reduced, while a 'selection' parameter controls how many flakes from the reduced set are selected for transport (both may vary from 0 to 100%). In the models presented here, reduction (i.e. flake production) and selection (i.e. flake removal) parameters were set to 100% in all configurations to highlight the influence of movement on model outcomes. Reducing these values produces qualitatively similar outcomes but constrains how much cortex can be separated from original nodules and dampens the range of potential variability (Davies et al.

2018). An additional parameter, 'carry-in', controls the percentage of a reduction set (again, 0-100%) that the agent is carrying upon entering the window of observation.

A detailed treatment of the Cortex Ratio calculation is beyond the scope of this paper but can be found elsewhere in the literature (e.g., Douglass et al. 2008; Lin et al. 2015; Phillipps and Holdaway 2016). However, it is important to recognise that Cortex Ratio values are sensitive only to the systematic removal or supplementation of cortex (surface area) in the assemblage. Since this is calculated through the sum qualities of individual objects, the pattern becomes increasingly difficult to *reverse*, in the sense that Lucas (2012) uses the term, with greater numbers of discarded artefacts (Davies et al. 2018). It is this irreversibility that we argue provides a window into the organisation of activity and its relationship to socio-ecological resilience.

3.2. Modelling moves

The tortuosity of an agent's movement path is modelled here by the Lévy equation (Brantingham 2006; Tsallis 1997):

$$P(l)=l^{-\mu}$$

where $P(l)$ is the probability of selecting a value with length l. Different settings for the parameter μ define probability distributions for step lengths, where high values produce distributions that favour smaller step lengths, while low values produce distributions where longer step lengths are more likely to result. The repeated selection of step lengths, coupled with a random direction between 0 and 359 degrees, results in movement paths that are more or less tortuous, increasing or decreasing the duration of an agent's occupation of the window of observation. Agents begin their movement paths by stepping into the window of observation, and their contribution to the record ends when their movement path takes them beyond the boundaries of that window.

Each occupation episode involves a single agent; therefore, the frequency of occupation episodes can be controlled by the number of agents used in each simulation run. Lower numbers of agents produce a record of less frequent occupation, while more agents produce a record of more frequent occupation. At the end of the simulation run, the lithic objects remaining in the window of observation are assessed, and Cortex Ratios are calculated. The result could be considered to represent a single archaeological assemblage produced from the sum of manufacture, movement, and discard behaviours over time in that space; therefore, a set of simulation runs is analogous to a sample of assemblages recorded across a landscape. This permits the assessment of how different arrangements of tortuosity and frequency of occupation would affect variability in artefact density and Cortex Ratio within a landscape, and it allows assessment of their suitability as proxies for connectedness/complexity.

3.3. Exploring the model to contextualise Rutherfords Creek assemblages

Simulations were conducted to demonstrate differences that might be expected from two distinct models of mobility; each run 100 times:

- 'Occupation' model: a constant number of agents (n = 100) move at a random level of tortuosity ($1 < \mu < 3$)

- 'Accumulation' model: a random number of agents ($100 < n < 500$) move at a constant level of tortuosity ($\mu = 1$)

Some parameter settings in both models are held constant to emphasise the influence of movement on resultant patterns. For example, both assume maximum reduction and selection of artefacts; that is, all cores are fully reduced, and all 20 flakes from each core are carried away by the agents. Lowering either of these parameters would mean more cortex would remain on or near the cores from which they are removed, depressing the overall variability in the outcomes. Both models also assume agents enter the window of observation carrying either 0 or 20 flakes. In the model, increased carry-in of flakes has the effect of increasing Cortex Ratios overall; middling carry-in values not explored here would have the effect of moving all values closer to 1 as import and export become more balanced. A more in-depth examination of the effects of these parameters can be found elsewhere (Davies et al. 2018).

The models presented here produce comparable variation in densities between runs but show distinct patterning in resulting Cortex Ratios (fig. 6), attributable to time spent reducing and discarding locally. The Occupation model, where tortuosity varies, but the number of occupation episodes does not, shows Cortex Ratios that are dependent on assemblage density. Instances where tortuosity is high, result in more redundant movements within the window of observation, increasing density as more material is discarded. Simultaneously, as agents deplete and replenish their stores, more local stone remains within the window of observation, keeping Cortex Ratios closer to a value of 1. Lower tortuosity results in less local discard, lower densities, and, because there is an increased probability that a longer move will take the agent and any stone it carries out of the window of observation, Cortex Ratios that deviate further from 1.

In contrast, the Accumulation model, where tortuosity is kept constant, but the number of occupation episodes varies, shows distribution of Cortex Ratios around a common mean that is consistent across density values. In these cases, agents perform similar activities each time they are in the window of observation. Increasing the number of agents performing these activities, thereby increasing the assemblage density through increased frequency of occupation, only reinforces the pattern in Cortex Ratios and decreases variance in outcomes.

For both models, carrying artefacts into the window of observation pushes Cortex Ratios to values greater than 1 as the cortex in assemblages is supplemented with extra-local cortical flakes. Beyond this, though, these "carry-in" models maintain the distinction between models of Occupation (in which Cortex Ratio values trend toward 1 with increased density) and Accumulation (in which a relatively constant value is maintained across densities).

The results of the simulation can contextualise assemblage attributes from Rutherfords Creek. Cortex Ratios for these assemblages vary between 0.11 to 1.42, with no obvious spatial clustering of high or low values within the creek catchment (Davies and Holdaway 2017). The ratios are also mainly below 1, suggesting more cortical artefacts are leaving these assemblages than are being carried into them. Despite notable variability at very low densities, these Cortex Ratios show no clear trend toward 1 with assemblage density (fig. 7). Instead, they are remarkable for their evenness across density values, a pattern that is consistent with the outcomes of an Accumulation model.

4. Discussion

The varying density of archaeological assemblages, and associated measures of artefact diversity, have been used as evidence for shifts towards less mobile lifeways and, by extension, been associated with more connected/complex forms of hunter-gatherer social organisation consistent with a *K*-phase (conservation phase) in the adaptive cycle (Cascalheira and Bicho 2013; Widlok et al. 2012;). Similar patterns appear in surface assemblages recorded at Rutherfords Creek, prompting the question of whether this is an example of a likewise connected/complex SES. However, the relationship between the archaeological measure and the theoretical expectation is not exclusive since variation in assemblage density could be explained either through localised differences in occupation intensity (expressed here as tortuosity) or frequency of visitation.

The juxtaposition of density (a measure of accumulation) with the Cortex Ratio (a measure of artefact dispersal) allows us to contrast generative mechanisms, as illustrated by the exploratory agent-based simulation. Simulations of different occupation intensities produce assemblages that show a density-dependent relationship with Cortex Ratios, while simulations of different frequencies of occupations lack this relationship. These variant outcomes are due to the relative opportunities for local manufacture and discard afforded by differences in the duration of stay within a window of observation.

The assemblages at Rutherfords Creek show no clear relationship between assemblage densities and Cortex Ratios, a finding consistent with simulated assemblages generated through repeat visitation and inconsistent with simulations that would indicate variable use of space concentrated around the creek catchment during the late Holocene. Within the context of the model, this patterning suggests repeated visitation combined with consistency in the use of stone across the landscape. This finding contrasts with narratives of decreased mobility and intensified occupation in Australia's arid zone more generally (cf. Smith 2013). This challenges mobility and resilience inferences based on variable assemblage density.

Furthermore, the assemblages show Cortex Ratio values with a collective central tendency of less than 1, consistent with regular selection and removal of cortical material (most likely flakes) from assemblages. Frequent removal of cortical material from assemblage localities suggests a strategy of regular mobility. Such a strategy may buffer against the effects of localised fluctuations in resource availability (Holdaway et al. 2013, 2015), enhancing resistance to transitions into substantially different basins of attraction. At the same time, regular provisioning with high utility flakes allows for greater flexibility (Douglass 2010; Douglass et al. 2008; Morrow 1996), which may have allowed the system to exist in a broader latitude of states (i.e. the width of the basin in figure 1). Whatever the case, these strategies aided, or at the very least did not impede, the ability of humans to maintain a presence at Rutherfords Creek during the late Holocene despite irregular fluctuations in the availability of resources.

It is important to recognise that any estimation of stability would be scale-relative and would not indicate a lack of *change*. As noted above, a resilience-based framework assumes that change is a necessary component of a resilient system. Even if the general mobility configurations used at Rutherfords Creek contribute to a general state of equilibrium, this would be a dynamic equilibrium: an emergent outcome of adjustments to smaller-amplitude or punctuated disturbances (Burkhard et al. 2011; Holdaway et al. 2015). More diffuse assemblages at Rutherfords Creek, which show greater variability, may be reflective of these shifts. However, the additive process that produces the Cortex Ratio means that as artefacts accumulate, the pattern becomes less reversible (*sensu* Lucas 2008), making it, in turn, less sensitive to smaller amplitude changes over time and more reflective of longer-term, larger-scale processes (Allen et al. 2014). This does not mean that changes were absent, but only that the scale of any behavioural changes that may have occurred at Rutherfords Creek was not sufficient to perceptibly modify the patterning in stone artefact assemblages given the resolution of the data under examination (Bailey 1983).

This brief case study illustrates connections between the formation of archaeological patterning through an adaptive mechanism like mobility and how these patterns interface with an interpretive framework based on resilience. As discussed above, patterns such as variation in artefact density have been used as part of typological schemes that categorise social systems by their resilience. Linking social forms and adaptive stages to the presence or absence of archaeological indicators offers a systematic interpretive framework, enabling the construction of historical narratives from a range of data sources. At the same time, typologies can essentialise archaeological phenomena, emphasising key attributes at the expense of variability (Marwick 2008; Shott 2010). This can limit critical consideration of alternative ways in which assemblages might be inscribed on the record (Knell 2012; Lucas 2012; Olivier 1999; Perreault 2019) or how they interface with the resilience of past populations (e.g. Torrence 2012). Such considerations are especially important with a record that accumulates semi-independently of the processes contributing to resilience.

Archaeological narratives built on typological approaches usually represent big picture trends (e.g. Bar Yosef and Belfer-Cohen 1992), but trends will always have exceptions (Hiscock 2008; Holdaway et al. 2016). Finding perspectives that balance both trends and variability is difficult but important as archaeological narratives are incorporated into discourse beyond the sphere of the discipline (Allen 2015). Resilience frameworks, which consider change at different scales to be a prerequisite of functioning SES, offer such a perspective. However, while adaptive cycles may be a ubiquitous feature of SES, their application to the past requires careful integration with the formation dynamics of archaeological signatures. By using formal modelling methods, this integration can be made explicit, clarifying the logic that supports interpretations of resilience and change in the past.

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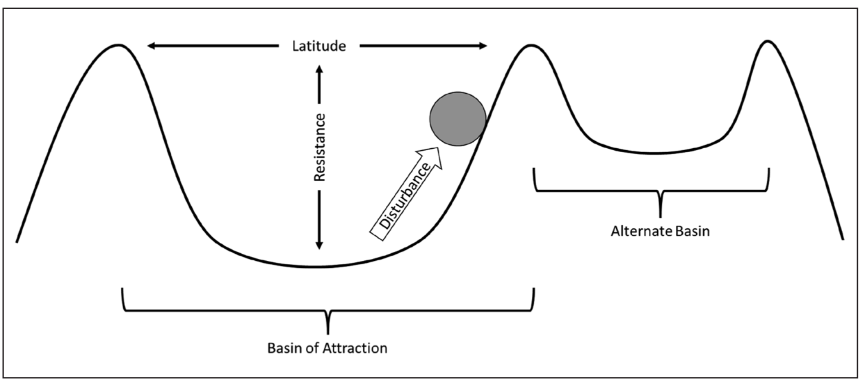

Fig. 1. Stability landscape model of system resilience.

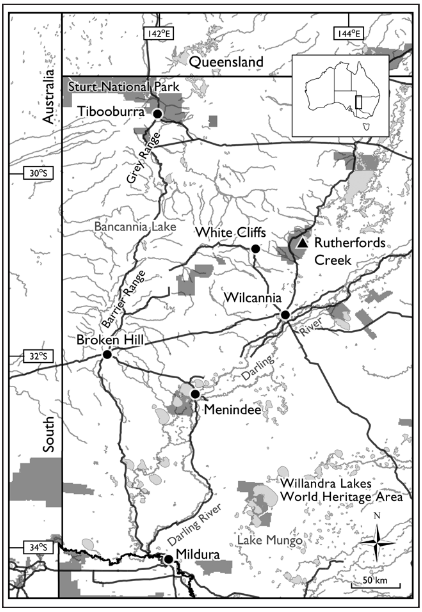

Fig. 2.
Western New South Wales, Australia showing the location of Rutherfords Creek (adapted from Holdaway and Fanning 2014).

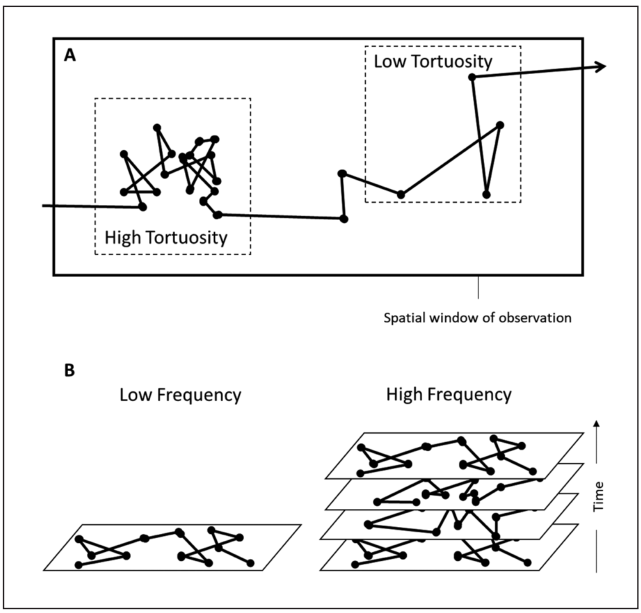

Fig. 3.
Conceptual models of movement in terms of A) tortuosity and B) frequency. Solid lines indicate movement paths; dots indicate artefact discard locations; enclosing solid rectangles indicate windows of observation.

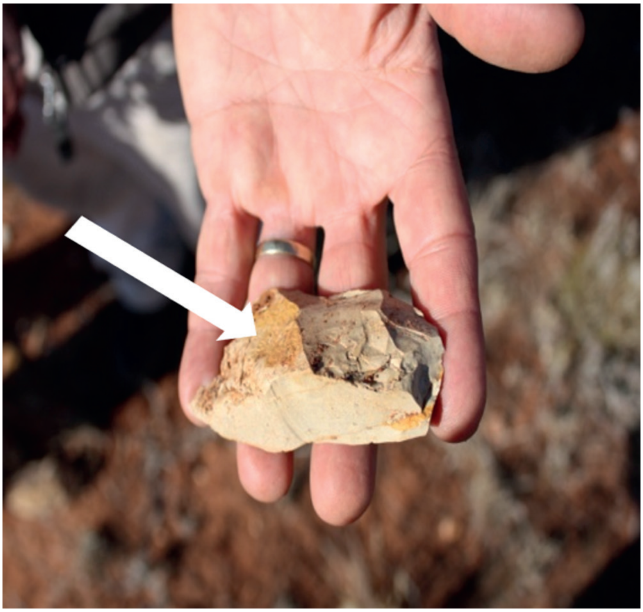

Fig. 4.
Silcrete flake from Rutherfords Creek with cortex indicated (photograph by Benjamin Davies).

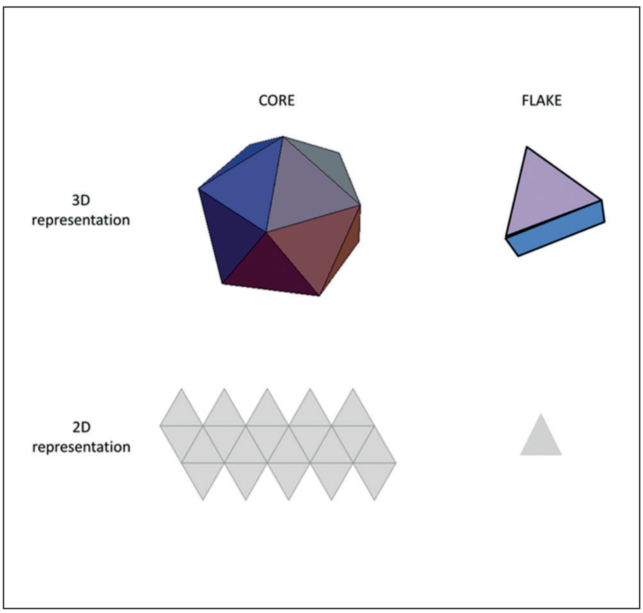

Fig. 5.
Polyhedral models of cores and flakes used in simulation (images adapted from Wolfram Alpha LLC, 2018. Wolfram|Alpha).

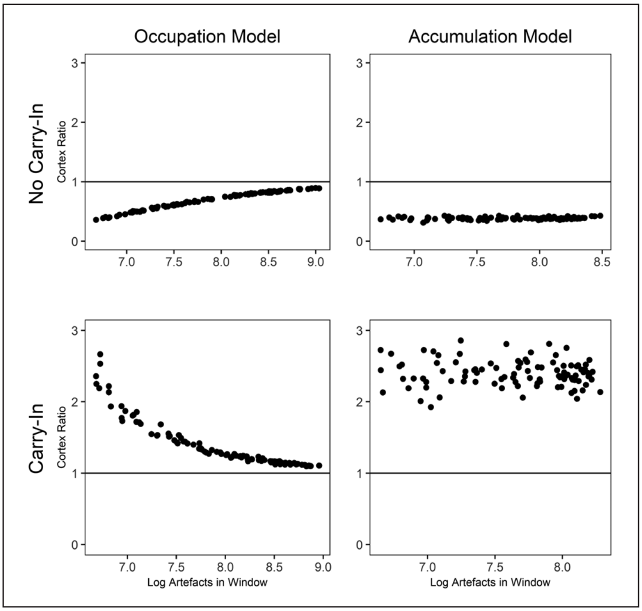

Fig. 6.
Cortex Ratios by log assemblage density produced by the Occupation and Accumulation models with no artefacts carried in (top row) and artefacts carried-in (bottom row).

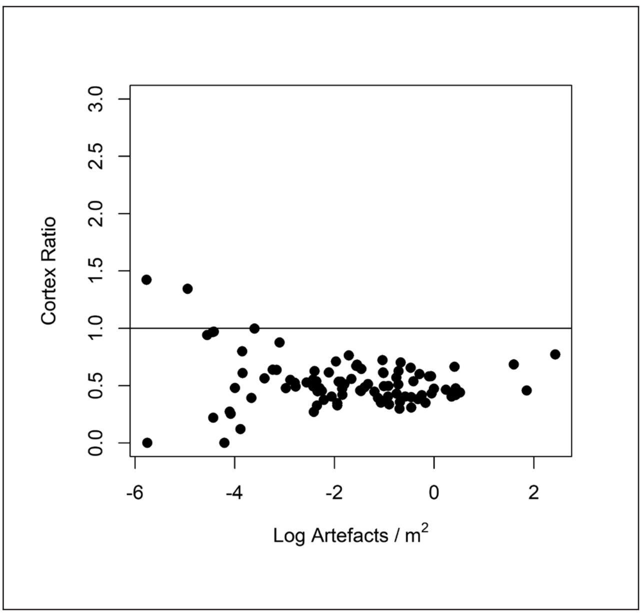

Fig. 7.
Cortex ratios by log assemblage density for surface scatters at Rutherfords Creek (n=93).