Anticipating societal collapse; Hints from the Stone Age

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Few aspects of human history are as mindboggling as the sudden disintegration of advanced societies. It is tempting to seek common patterns or even draw some lessons for modern times from the many ancient cases of societal disintegration. In PNAS, Downey et al. (1) report that universal warning signals of reduced resilience systematically preceded the collapse of Stone Age societies. Might similar indicators of fragility be relevant in modern times? Of course, the nature of human societies has changed entirely. However, there are at times striking parallels between stories of collapse even if they happened in entirely different periods. Consider the abrupt abandonment of the iconic alcove sites in Mesa Verde by the ancestral Puebloan people: the greatest "vanishing act" in prehistoric America (2). Archaeological evidence now reveals that before Pueblo peoples massively migrated in the mid-to-late 1200s, there had actually been a slow build-up of tension (3, 4). Over a century of drought, violence, and political turmoil drove increasing numbers of people into the Mesa Verde region, which was relatively productive for farming, straining carrying capacity as well as cultural traditions and resulting in destabilizing conflicts. Portions of the northern Southwest began to empty out in the first decades of the 13th century and by the mid-1200s even the favored central Mesa Verde region was starting to lose population, well in advance of the "Great Drought" beginning in the late 1270s that seems to have given the final blow. Now, Syria is the scene of a sudden massive exodus, and some aspects of the complex situation do seem to echo the Pueblo story. The Fertile Crescent has likely been experiencing the worst drought in 900 y, making subsistence farming in the countryside extremely challenging and driving millions in Syria to the cities, where tensions increased (5). An incident—torture of a group of teenagers that had painted antigovernment graffiti on the walls of a school—eventually sparked the violent conflict, leading up to an accelerating mass migration with millions on the move. Drought, aggregation in cities, cultural clash, violent conflict, and exodus appear as common elements in otherwise entirely different settings. On closer inspection, there is of course a large diversity in the numerous documented cases of societal crumbling, both in the drivers and in the way change unfolded (6). Dramatic demographic collapse of resource-strapped societies, as in the Rapa Nui (Easter Island) people and the Greenland Norse of the early 15th century (7, 8), represent one end of the range, whereas in other cases (including the Pueblo vanishing act) people abandoned the old physical and social structures to accommodate new ways of living (9).

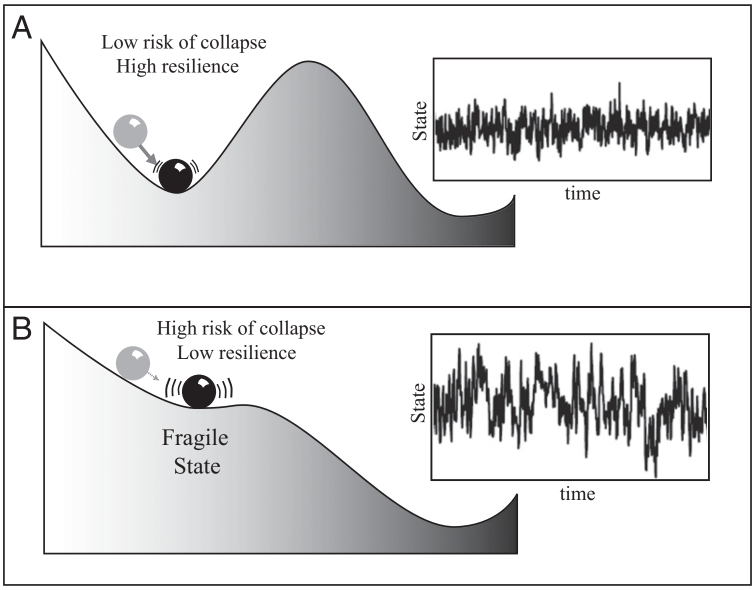

Fig. 1. Indicators of the loss of resilience in the vicinity of a tipping point. (*A*) Far from a tipping point, the state of the system (the ball) is resilient: the basin of attraction is large and perturbations will not easily drive the system toward an alternative state. (*B*) If a system is close to a tipping point the basin of attraction will be small, and a perturbation may easily push the system into an alternative basin. Note that the actual state of the system by itself does not reveal such fragility. However, dynamics around the equilibrium differ from those when the basin of attraction is large (as in *A*). In the fragile state (*B*), the recovery rate from a small perturbation is smaller (arrow), and as a result the fluctuations in a stochastic environment will tend to be larger and more time-correlated, as shown in the *Insets* (modified from refs. 22 and 23).

Perhaps the single most-intriguing aspect across stories of collapse is the speed with which massive

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Author contributions: M.S. wrote the paper.

The author declares no conflict of interest.

See companion article on page 9751 in issue 35 of volume 113.

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change can be precipitated. This rapidity is also the aspect that makes such events feel so relevant from a modern perspective. How is it that a once-thriving society can so suddenly fall apart? Could it happen again? If so, is there any way we can foresee where and when?

If collapse is just driven by extreme events, such as epidemics or monster droughts, it may be entirely unforeseeable. However, if the underlying cause is a gradual loss of resilience, causing societies to become fragile, we might be able to predict where collapse is most likely. Fragility of states is typically estimated indirectly from social, economic and political risk factors (10), but now Downey et al. (1) suggest that the risk of societal collapse might also be measured directly from observed dynamics that signal a loss of resilience. Their inspiration comes from systems theory. It has become clear over the past years that loss of resilience may be inferred from subtle changes in dynamics in a wide range of complex systems as they approach a tipping point (11). The underlying generic phenomenon is that recovery from small perturbations becomes slow if resilience becomes small, resulting in elevated temporal autocorrelation (memory) and variance under natural fluctuating conditions (Fig. 1). Loss of resilience may happen in many situations, but the vicinity of a tipping point is a particularly interesting one, as here it signals an increased risk of entering an avalanche of self-propelling change. Indicators of such "critical slowing down" before a tipping point have been demonstrated in laboratory populations (12, 13), paleo climate (14, 15), and ecosystems (16). It has been speculated that societal shifts should be no exception to the rule that a measurable loss of resilience forewarns a tipping point (17), but so far it had been challenging to show this from the data.

Now Downey et al. (1) show evidence for such critical slowing down before societal crashes, and it comes from surprisingly ancient times. About 8,000 y ago, Europe was the scene of a revolution changing the face of the Earth. Originating in the Fertile Crescent (today the scene of an exodus), demographically aggressive agricultural societies and their techniques began spreading east and west, displacing, engulfing, or modifying foraging societies. Neolithic settlements were in a number of marked regions, and Downey et al. estimate population densities in each region from the number of settlements that were in use at any given moment, using radiocarbon dating reconstructions. Such reconstructions suggest that populations were not steadily increasing. Instead, periods of growth typically ended in a collapse of numbers (18). The novel finding now is that leading up to such collapse, the dynamics of populations as reconstructed from summed probability densities of radiocarbon-dated archaeological sites typically show rising variance and rising temporal correlation, tell-tale signs of declining resilience (Fig. 1).

What could have caused these early farming communities to stumble or crash? Would diseases or conflict be involved? Downey et al. (1) suggest that deforestation and overexploitation of the land might have played a role. In most places, the authors find evidence for repeated cycles of boom-and-bust with a length of 400–1,000 y. Would that be the time for the land to recover? We do not know, but similar cycles have been found for a later period in estimated population numbers in South America after colonization of the continent (19). The simplest interpretation could indeed be one of classic consumer–resource cycles. However, one may wonder if societies would not notice declining conditions in time to move or change strategies before a crash occurred.

One theory is that societies tend to resist change until it is too late for smooth adjustments. Indeed, some fundamental mechanisms that hamper our capacity for change have been well documented. There is the "sunk-cost effect" preventing people from abandoning acquired property (or ways of living or beliefs) even if that would rationally be better (20). Then there is the "by-stander effect," leading one to copy the behavior of others in case of doubt. This effect is known for explaining why often no-one in a crowd of by-standers comes to the rescue (21). Finally, elites may have a vested interest in maintaining the status quo, thus delaying societal change (8). Certainly such mechanisms are not specific to the Stone Age. Indeed, it may be argued that in more sophisticated societies with more elaborate physical structures and social systems, some of those mechanisms that prevent change might become stronger rather than weaker.

This way of thinking naturally leads to the question as to whether the findings from the Neolithic might have any relevance for interpreting current challenges to societies. It would be an open door to say that a society can prevent collapse by adapting in time. However, if we take that reasoning through, could it be that most of the societal "collapses," such as violent civil conflicts and mass migrations, happen in fragile situations resulting from a gradual loss of resilience? If so, would there be ways to use the toolbox of systems science and big data to complement current risk markers by scanning the globe for empirical indicators of resilience?

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