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Transitional change in proto-buildings: a quantitative study of thermal behaviour and its relationship with social functionality

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ABSTRACT

The almost universal transition from 'brushwood' huts to 'pithouses' to above-ground rectilinear huts constitutes an example of architectural convergence, having occurred in numerous culturally unrelated regions around the world. This transition was accompanied by a pattern of change in the way these proto-buildings performed thermally. A quantitative study using engineering-analysis, outlined here, shows that the thermal microclimatic range and potential for selective thermal control (the building's thermal capacity) gradually increased throughout the proto-building phase. This means that the range of thermally dependent functions that the occupants were capable of performing would have correspondingly increased throughout the phase. This pattern, of increasing thermal capacity and the potential for social functionality that is present throughout the proto-building phase, is also present throughout the vastly longer term trajectory of change evident in the built environment generally. Over time, change in the built environment has tended towards the prevalence of classes of buildings that possess selectively adjustable thermal systems, systems that can accommodate diverse and changing social options.

1. Introduction

The almost universal transition from 'brushwood' huts to semisubterranean domed 'pithouses' to above-ground rectilinear huts constitutes an example of early architectural convergence, having occurred in antiquity in numerous culturally unrelated regions around the world (Figs. 1 and 2). Lightweight 'brushwood' huts represent the earliest recorded proto-buildings (Nadel and Werker, 1999), although these most likely superseded earlier rudimentary 'structures': windbreaks and shade structures. 'Brushwood' huts were in turn predominantly superseded by 'pithouses' which were, in turn, predominantly superseded by above-ground rectilinear huts (Stea and Turan, 1993), although these various transitions occurred at different absolute moments in time and varied in nature from region to region (Cordell and Gumerman, 1989; Rocek, 1998; Flannery, 2002). The earliest single-roomed above-ground rectilinear huts subsequently developed into the complex rectilinear building complexes that have generally dominated the built environment ever since.

In the Old World, the transition from domed 'pithouses' to above-ground buildings was relatively rapid and wholesale, and complete by approximately 6500 B.C. (Byrd, 2005). In the New World, pithouses continued to be used alongside pueblos for many years, during which time the relative depth of the pithouses actually increased (Stuart and Farwell, 1983). Ultimately, however, these pithouses too fell out of use, by approximately 1000 A.D. Note that the term 'pithouse' is most commonly used to refer to the circular, semisubterranean structures of the American Southwest, but in Southwest Asia most Epipalaeolithic and numerous Neolithic structures were of broadly similar construction, ranging from round pits to floors cut into the sides of a slope (earth integrated). The term can therefore be equally applied to similar types of construction (Rocek, 1998: p. 200).

What might account for this example of architectural convergence? It has been argued that the transition from lightweight huts to 'pithouses' was driven by a human desire for increased thermal 'comfort' (cf. Stuart and Farwell, 1983; Gilman, 1987; Farwell, 1981). It is true that the ambient temperatures experienced inside semisubterranean 'pithouses' are far milder compared with those inside lightweight 'brushwood' huts. The greater thermal mass of 'pithouses', provided by the integrated surrounding earth, dampens out daily and seasonal temperature extremes, creating warmer nighttime interiors in cool climates and cooler daytime interiors in warm climates (Labs, 1980; Pearlmutter et al., 1983; Baggs et al., 1991). However, this argument does not explain the variability between 'pithouses' evident in the archaeological record (Wills, 2001), nor, and more importantly, the subsequent transition to above-ground huts which were of a lighter thermal mass than the 'pithouses' and which were far more exposed to outside temperature extremes.

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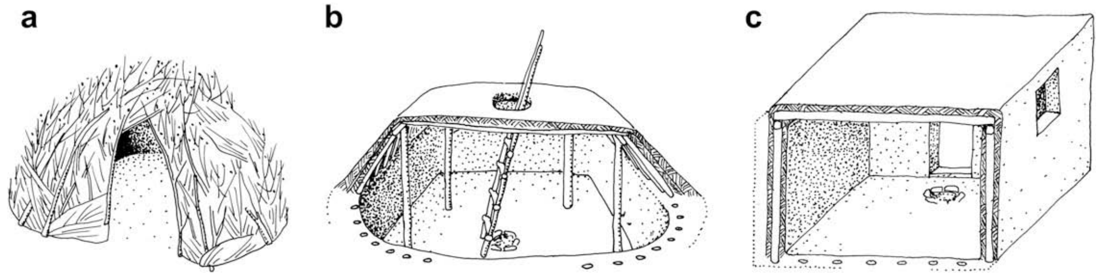

Fig. 1. Generic (a) 'brushwood' huts, (b) 'pithouses' and (c) above-ground rectilinear huts.

It is, however, significant that each transitional change throughout the proto-building phase was accompanied by a general increase in the microclimatic temperature range and degree of controllable adjustability that the structures were capable of achieving. That is, the thermal capacity of the structures increased incrementally throughout the phase. This means that the range of thermally dependent functions that the occupants were able to perform inside the buildings would have correspondingly incrementally increased, as their range of thermal choices and potential for selective thermal control gradually increased. Tasks that required very specific and/or unique thermal conditions would have become increasingly possible. Certain tasks can be successfully performed outside, an environment that is thermally uncontrollable without additional means, but the more complex the task, the more complex the thermal and physical environment must be for its successful completion. A simple hut can have its doorway either open or closed, or only partially closed, thus making the natural air movement inside more controllable. But the capacity for even further control of the natural elements becomes available in structures that incorporate multiple openings, different levels, different spaces, different sub-spaces, and different means of heating and ventilating each space. Lithics can be made outside, but milling grain is chancy. Rugby can be played outside, but making a chronometer outside is difficult. Making gunpowder outside is foolhardy.

The pattern of increasing thermal capacity evident throughout the proto-building phase, and discussed here, is representative of a quantitative increase in the thermal capacity of classes of buildings and of the built environment over time generally, from the earliest built structures through to at least the pre-industrial era. Classes of buildings that possess selectively adjustable thermal systems, systems that can accommodate diverse and changing social options, have tended to ultimately prevail (Wilkins, 2007; Wilkins, in press). This paper outlines a set of field experiments that quantify the thermal capacity of 'brushwood' huts, semisubterranean domed 'pithouses' and above-ground rectilinear huts, in terms of their microclimatic temperature range (thermal choices) and degree of controllable thermal adjustability (thermal control), these being the two components of a structure's thermal capacity (Ong, 1995).

2. The thermal analysis

The material characteristics of the proto-buildings were ascertained from archaeological excavation reports (e.g. Byrd, 2005; Martin & Rinaldo, 1947; Wills, 1996) and the thermal choices and thermal control were empirically ascertained via engineering-analysis. Engineering-analysis is a method of real-time experimentation by which the operational functionality of complex systems, such as thermal systems, can be measured and understood (Carlson and Doyle, 1999; Jen, 2005). The particular application of engineering-analysis utilised here works on the principle that when generic testcase buildings (buildings that are composed of the base-line thermal features held in common by a statistically large set of real buildings) are tested for thermal operational functionality a corpus of detailed thermal information is acquired that is generically extrapolatable to the real buildings, as well as to

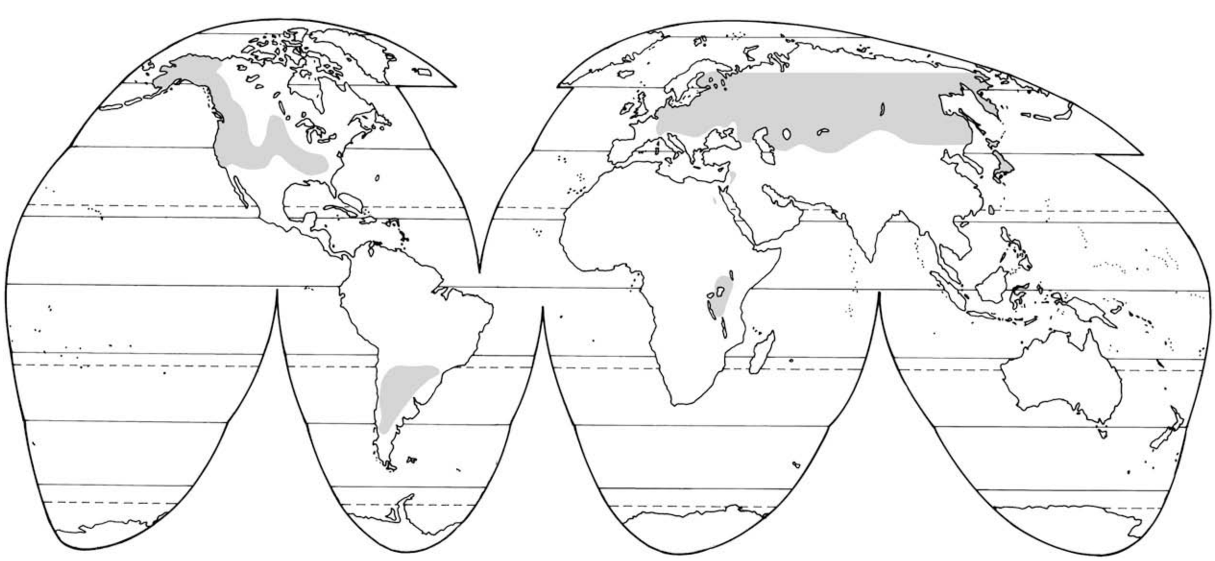

Fig. 2. Distribution of 'pithouses' in the archaeological record (after Gilman, 1983: p. 84; Wilkins, in press).