Infidelities of fossil assemblages

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It is widely accepted that palaeontologists and earth scientists in general should be cautious in extrapolating modern processes and rates to the geologic past (Gould 1965). A chance of error is nested in the cyclic behavior of the Earth system. At the scale of the Phanerozoic, the Holocene forms part of an icehouse interval and the present world’s climatic belts are to be compared only to those occurring in similar glacial-interglacial Earths, Ordovician or upper Palaeozoic, for instance. On the other hand, when looking at the Cambrian, mid-Palaeozoic or Paleogene, we are offered with visions of a greenhouse planet, a ‘strange old world’ indeed (Kaufman 1987; Pfefferkorn 1995; Clyde 1999; Soreghan 2004). At finer temporal scales a hierarchy of sea level and climate variations produces cycles with frequencies spanning orders of $10^4$–$10^6$ my (Vail et al. 1991). When examining the geologic record under the perspective of high-frequency cycles, the Holocene becomes a thin skin. We live and act in a time of transgressed shelves, while the thickest parts of the sedimentary record were built at times of progradation, during sea level lowstands and highstands (Clifford 2004). Sea-level lowering during glacial times dramatically impacted the physiography of the continental margins, leading to strong erosion, sediment bypass of coast and shelf areas and to exceptional sediment supply to the deep basins. Although everyone should be aware of the need to reform the uniformitarian approach, inferences are still directly drawn from the Modern to the past in an understatement of the risks involved in forgetting historical pathways. By placing the focus on the issue of spatial fidelity of fossil assemblages, the non-uniformitarian approach is here re-emphasized and an invitation is made to consider its influences in taphonomy.

Actualistic taphonomic studies suggest that out-of-habitat transport is not an overwhelming problem in ordinary level-bottom taphonomic settings (Kidwell & Flessa 1996; Behrensmeyer et al. 2000). Allochthonous is considered to be frequent only in the presence of a steep depositional gradient or in settings with episodically very high pulse-type energy (Kidwell & Bosence 1991, p. 158). Donovan (2002) has already made the point that steep depositional gradients may be much more common than generally assumed, and actualistic studies support his view (Hubbard 1992; Hohenegger & Yordanova 2001). Here, we raise the point that also on gently sloping shelves considerable shell transport may be more common than indicated by actualistic studies. Transport most likely will result from historically rare, but geologically frequent, catastrophic events: a single major storm or turbidity current over decades or centuries may be sufficient to transport skeletal remains into deeper water environments, cover them with other transported clastics and increase their likelihood of being preserved (e.g. Bries et al. 2004). Under the ever-ruling second law of thermodynamics – methodological uniformitarianism works – we expect shells to appear where they are not (but see Flessa 1998). It may therefore be premature to deduce lack of out-of-habitat transport for fossil assemblages from such environments, because none of the actualistic study sites has yet finished its taphonomic history. It is also suggested that the importance of shell transport could be underestimated in many Recent and fossil assemblages, because thin event beds are frequently reworked by bioturbation into the normal sedimentary record (e.g. Sepkoski et al. 1991; Zuschin & Stanton 2002; Keen et al. 2004). To make things worse, tempestitic and turbiditic deposits can only be seldom related to their source areas, which are rarely preserved in the geological record. This discrepancy reflects a bias against intertidal and shallow subtidal settings, typically used for actuo-palaeontological studies, without considering that, due to erosion, they are probably bound to be lost, especially in the older geological record.

The fossil record is full of shelly event beds. A survey of the literature will convince even the most skeptical that most shell beds are produced by geologically rare and catastrophic events. Tempestitic and turbiditic shell beds are among the most common skeletal concentrations throughout the Phanerozoic (Kidwell & Brenchley 1984; Li & Droser 1997; Kowalewski & Bambach 2003). Based on actuo-palaeontology, however, the view is that spatial fidelity is generally high. Should we adhere to this knowledge when studying fossil assemblages? Interestingly, the view that out-of-habitat displacement of skeletal material can be a common feature of fossil shell beds, once held by palaeoecologists (Johnson 1960; Park 1968), was kept alive in the works of sedimentary geologists (Goldring & Bridges 1973; Kazmierczak & Goldring 1978; Mutti et al. 1996), against a mounting wave of actuo-palaeontological studies. Why was this so? Perhaps because researchers familiar with the fact that gravels, mud clasts, and sands do get transported over long distances, expect bioclasts to be transported too. In fact, hyperpicnal flows and related turbiditic currents, among the most important factors of delta progradation (Mutti et al. 1996, 2003; Plink-Björklund & Steel 2004), can carry shells and other organic remains up to hundreds of miles from their source area (van Straaten 1960; Sarnthein & Bartolini 1973; Pilkey & Curran 1986; Mutti et al. 1996, 2003; Squires 1998; Donovan 2002; Beavington-Penney 2004). Accordingly, many direct analytical studies of fossil shell beds reveal palaeoecological and taphonomic evidence that bioclasts were frequently carried out of their life site (e.g. Plaziat 1984; Fürsich & Flessa 1987; Dominici 2004; Tomasovsky 2004; Zuschin et al. 2005; Beavington-Penney et al. 2005). Such evidence suggests exercising caution when interpreting taphonomic facies and approaching the study of palaeocommunity composition and diversity patterns from shell beds.

Further attention should be paid to the structural setting from which we derive our models. Many of the above-mentioned palaeontological studies are from tectonically mobile basins in collisional belts, where, due to mountain building, high quantities of sediment are discharged in high-subsidence basins. A variety of fluidal sediment gravity flows (Mutti et al. 1996, 2003; Benvenuti & Martini 2002; Plink-Björklund & Steel 2004) occurred in flood-dominated fluvo-deltaic systems, delivering huge volumes of sediment to rapidly subsiding basins and displacing bioclastic material. In Holocene transgressed and slow-subsiding coastal and shallow marine areas, allochthonous shell beds are expected to be very rare, and the few high-magnitude events that punctuate an overall condition of ‘normal’ processes determine very limited displacement. Spatial fidelity of modern assemblages is expected to be generally high, whereby low sedimentation rates lead to mixing of shells produced at significantly different times (Kowalewski & Bambach 2003). In contrast, allowing for the opposite condition at times of maximum progradation of fluvial and coastal systems, we would expect low spatial-fidelity of fossil assemblages, at the same time predicting time-averaging to be less significant than suggested by modern shell beds.

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