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A question of uniformitarianism: Has the geological past become the key to humanity's future?

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ABSTRACT

The acceptance of the Anthropocene as a new unit of geological time presents challenges for uniformitarian geologists. The principle of uniformitarianism, and relative merits of uniformitarian concepts in general, are subject to fierce debate. While the present may hold the key to the past, it is increasingly difficult to make accurate, credible, and useful inferences of future behaviour using the geological past as a guide. Complex projections on long (>100 years) timescales will never be completely accurate, as the actions of, an interactions within, human societies, will never be fully known. Global population growth and the consequences of industrial progress appeal more to a catastrophist, rather than a substantive uniformitarian, model. However, the quest for sustainability has led to a resurgence of interest in scrutinising the geological record to construct long-term solutions. Increasingly, a basic geological grounding is essential in multi-disciplinary studies that aim to offset or reduce deleterious anthropogenic impacts. The anthropogenic present must act as a filter through which the past is interpreted when searching for keys to the future.

1. Introduction

Engraved in the minds of every first-year geology student, the paraphrased axiom 'the present is the key to the past' is still debated today as it was during the time of Hutton (Gould, 1965; Baker, 2014a; Knight and Harrison, 2014). Many natural processes operating in the past, as inferred from geological evidence, could continue to operate in much the same way (Hutton, 1795). However, population growth and the inexorable rise of industry have motivated an addendum: the geological past could necessarily hold the key to the future. The stratigraphic record can be usefully exploited across a variety of timescales. At the longest (million-year) scale, the location and extent of hydrocarbon-bearing source and reservoir rocks can be predicted on the basis of onshore stratigraphy, drainage, and uplift histories (White and Lovell, 1997; Macgregor, 2012; Roberts et al., 2012; Paul et al., 2014). Over thousands of years, oxygen isotope ratios have been used as a proxy for ice volume, and so palaeoclimate; and discrete events like mantle plume activity and fault movement can also be inferred from the record (Shackleton and Opdyke, 1973; Schwartz and Coppersmith, 1984; Ernst and Buchan, 2003).

Geological history therefore provides an important template for the future of humanity: not just in terms of our survival as a species, but also in informing our approach to the future. Only over the last hundred years or so has the relevance of the geological past – through new technology (such as improvements in computing power) and a more comprehensive understanding of the governing processes – been drawn into sharp focus. However, the explosion in population has bred irrevocable change: the conceptual timescale for change of any kind is becoming progressively smaller, and it is the activity of the anthropogenic present that dominates our future outlook. For instance, projections of future climate scenarios, 'peak oil', and the availability and distribution of freshwater have changed dramatically even over the last 40 years (cf. Hansen et al., 1981; Hulme et al., 1999; MacDonald et al., 2012). Thus, while geological history is the 'key' in this context, it could potentially prove less useful in unlocking an uncertain and volatile anthropogenically modified future. As the quest for sustainable living takes on a mantle of new importance, the geological past will become an important area in which to start looking; a better understanding of past natural processes will usefully inform the future of our energy and water resources.

2. The geological record

To what extent can geological processes, often operating tens of millions of years ago, provide plausible predictions and explanations for future behaviour? Baker (2014a) highlights a logical flaw in the posing of this question. Any observation of past

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behaviour does not set a logical imperative that such behaviour should be replicated in the future (i.e. the inductive problem: Baker, 2014a). Nothing can be observed causally; rather it is the phenomenon of causation that should require a particular phenomenon to occur, one way or the other. In fact, absolute predictions lie within the realms of physics; such predictions are not necessarily grounded in (geological) reality. It is therefore more prudent to use the geological record to assess what can plausibly happen, now or in the future, rather than asking it to furnish credible and accurate predictions as to what *will* actually happen.

The interaction of two factors has modified the way in which geological history can be exploited: a revolution in the practice of Earth Sciences, and technological progress. In the former case, we are only recently (and tentatively) moving away from the antecedent reductionist approach, and in doing so, appreciating the complexity of the earth and how it must be treated in a broader, more holistic manner. To take an example, the intricacies of crustal physical and mechanical behaviour cannot be resolved with an understanding of geodynamics alone. Individual contributions have also had an enormously positive effect on broadening the scope of Earth Science: Wegener's Continental Drift Theory laid the foundations for fields as diverse as climatology, basin analysis, and the geodynamo, thus allowing for more sophisticated and integrated numerical models of future natural phenomena (Le Pichon, 1968; Habicht, 1979).

In terms of technology, larger and more powerful computers can run numerical simulations of enormous complexity; developments in remote sensing have allowed for the cover of much wider areas than hitherto; and improvements in the accuracy and precision of dating have further increased with new concepts such as High-resolution Event Stratigraphy (HIRES) and sequence stratigraphy (Vail, 1987; Kaufmann, 1988; Pohl and Van Genderen, 1998). Moreover, with the advent of the internet and lower travel costs, more extensive collaborations have become possible; this globalisation has allowed the Integrated Ocean Drilling Program (IODP) to interrogate an enormous volume of data, producing ground-breaking research on the Earth's history and structure (e.g. Wilson et al., 2006).

Thanks to the increasing significance of environmental change in recent years, relics of the geological past (including the basic foundations laid by Hutton, de la Beche, Walther, and Lyell) are now being studied by those who may have previously discounted them. Meteorologists, ecologists, and high-energy physicists are all keen to inculcate at least a basic geological knowledge in themselves (e.g. Meyerhoff, 1970; Gorham et al., 2002). Indeed, the ostensibly forgotten geological concepts – as opposed to the tangible products – of the past are being resurrected as we face the future. The atmospheric CO_2 that has a significant effect upon climate is an idea originating in the 19th century; revisiting it has created the intellectual environment in which co-ordinated efforts can be made to predict the consequences of myriad potential future climate scenarios (Hansen et al., 1981). Similarly, together with the deleterious effects of unmitigated population growth on the environment, the concept of palaeoautecology – the relationship of small groups to their immediate surroundings – has resurfaced, for instance in Hudson's classic study on salinity-controlled biofacies of mid-Jurassic times in Skye, UK (Hudson, 1963). It is undoubtedly true that the geological past has become a key to our future somewhat indirectly through scientific advances and discoveries of recent times. The last 20 years have seen a dramatic rise in the number of articles dealing with links between environmental geosciences and the fate of humanity (e.g. Williams, 2000; Lovelock, 2007; Zalasiewicz et al., 2008; Szerszynski, 2012).

While it is difficult to draw accurate and credible predictions directly from the geological past, it can still usefully illuminate the future, through an understanding of the processes that could potentially take place. However, the degree to which it can do so is a question of time: the immediate day-to-day future; millennial-scale; or longer, a geological future. First, while for some the concept of 'humanity's future' might evoke catastrophic scenes of global warming-related inundations or meteorite impacts, others might look upon the phrase in a more benign light. Natural hazards such as earthquakes continue to claim many lives each year, and are still very poorly understood. However, the arrival of new radar interferometry (SAR) techniques has the potential to resolve many such (seismogenic) problems (Rosen et al., 2008). Reliable medium-range forecasts could be produced by mapping past geological strain accumulation globally, thus minimising the loss of life (Bürgmann et al., 2000; Rosen et al., 2008). On a considerably longer (and perhaps more significant) scale, several recent state-of-the-art methods have allowed for more accurate predictions of the pattern and timing of future climate variations. A revolution in our understanding of the driving factors behind ice age cycles was sparked by the discovery of microscopic bubbles of ancient air trapped within present-day ice sheets (Shackleton and Opdyke, 1973).

3. Uniformitarianism

Uniformitarianism is a salient pillar of geology. The geological past can therefore be interrogated in relation to present geological processes. The extent to which human action has changed (and is changing) the real-world realities that form the basis for uniformitarian ideas is relative and highly subjective in a geological context (Baker, 2014a; Knight and Harrison, 2014). The near-surface geological record is a function of both an inherent natural instability and anthropogenic change. The Gaia concept formulated by Lovelock favours disruptive physiochemical changes as the mechanism largely responsible for biological evolution and biodiversity, and the maintenance of a preferred climatic and geochemical homeostasis on earth (e.g. Lovelock, 1995, 2007). Lovelock (1995) views the earth itself as an actual living and self-regulating organism, evolving itself while controlling both biological evolution of plants and animals and geological evolution of the crust. However, traditional earth scientists maintain that the Earth's climatic pattern, for instance, is more geological than biological, therefore being more vulnerable and less robust (Hansen et al., 1981). Indeed, the geological record remains best suited to elucidate cyclic patterns such as sea-level variation and those within magnetostratigraphy (e.g. Meyerhoff, 1970; Shackleton and Opdyke, 1973).

Discussion of the relevance and use of uniformitarian ideas in Anthropocene time has been ongoing for some time (e.g. Gould, 1965; Baker, 2014a; Knight and Harrison, 2014). Gould (1965) originally divided such ideas into two different classes. The first, substantive or 'strong' principle of uniformitarianism includes the uniformities of kind, degree, rate (gradualism), and state (steady-stateism). These concepts, claiming how the earth is supposed to behave, have largely been discredited in light of the Anthropocene (Gould, 1965; Knight and Harrison, 2014). The second class, methodological or 'weak' uniformitarianism, refers to an approach common to many geographical and geological disciplines in which suggestions based on present-day observations are applied to the past or future. Knight and Harrison (2014) consider 'weak' uniformitarianism to be based on 'disconnected, circular reasoning' and reject its principles for two reasons: first, it does not account for the often dramatic anthropogenic effects on earth systems; secondly, it cannot account for the complex behaviour of these systems, including non-linearity, time lags, the coupling of climate and tectonics, and feedback loops. However, they note