# THE USE OF GEOGRAPHIC INFORMATION SYSTEMS IN STUDIES ON THE COMPLETENESS OF THE FOSSIL RECORD


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## 1. Introduction

Many recent studies have identified positive correlations between fossil occurrences and the amount of rock preserved per geological time bin. There are two competing explanations for this persistent covariation: (1) the fossil record is severely biased by the amount of sedimentary rock preserved per time period; (2) both the rock and fossil records have been driven simultaneously be an environmental common-cause mechanism. However, most studies have been carried out at global or continental scales, using arguably vague and imprecise geological data, often in the form of outcrop areas devised from synoptic global geological maps or formation counts obtained from the Paleobiology Database (PaleoDB).

In combination, Geographic Information Systems (GIS) and remote sensing, offer a powerful tool for the capture, storage, display, and analysis of geospatial data and, up until recently, had been sparingly used in paleontological studies. In combination with digital geological data (i.e. British Geological Survey digital maps) and paleontological data (i.e. PaleoDB), GIS can be used to directly compare the rock and fossil records as well as adding a critical spatial dimension where current studies have simply analysed diversity metrics through time.

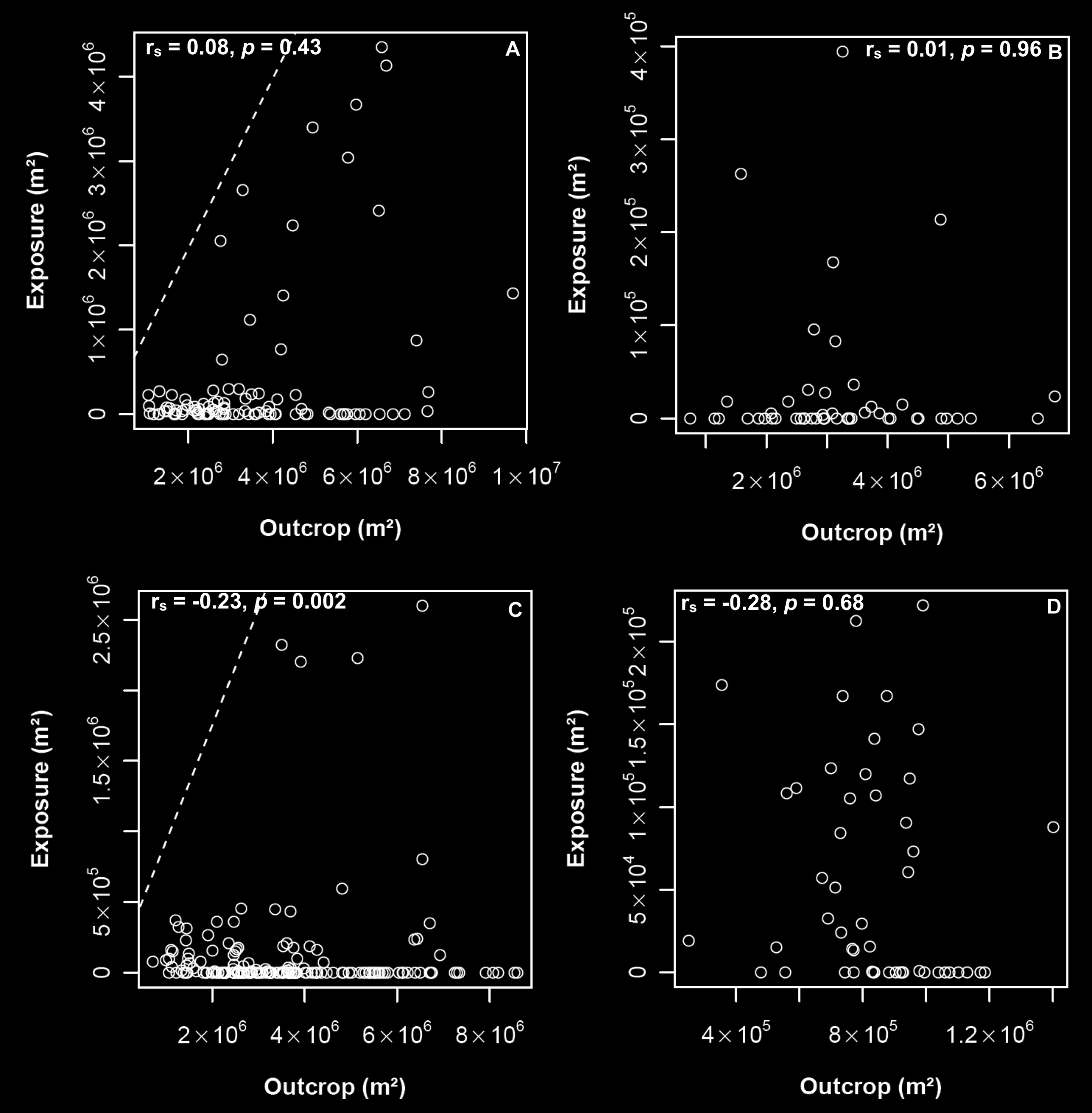



**Figure 1.** Correlation plots of outcrop area and exposure in: **A.** California; **B.** New York State; **C.** Australia; **D.** England and Wales (Dunhill 2011, 2012).

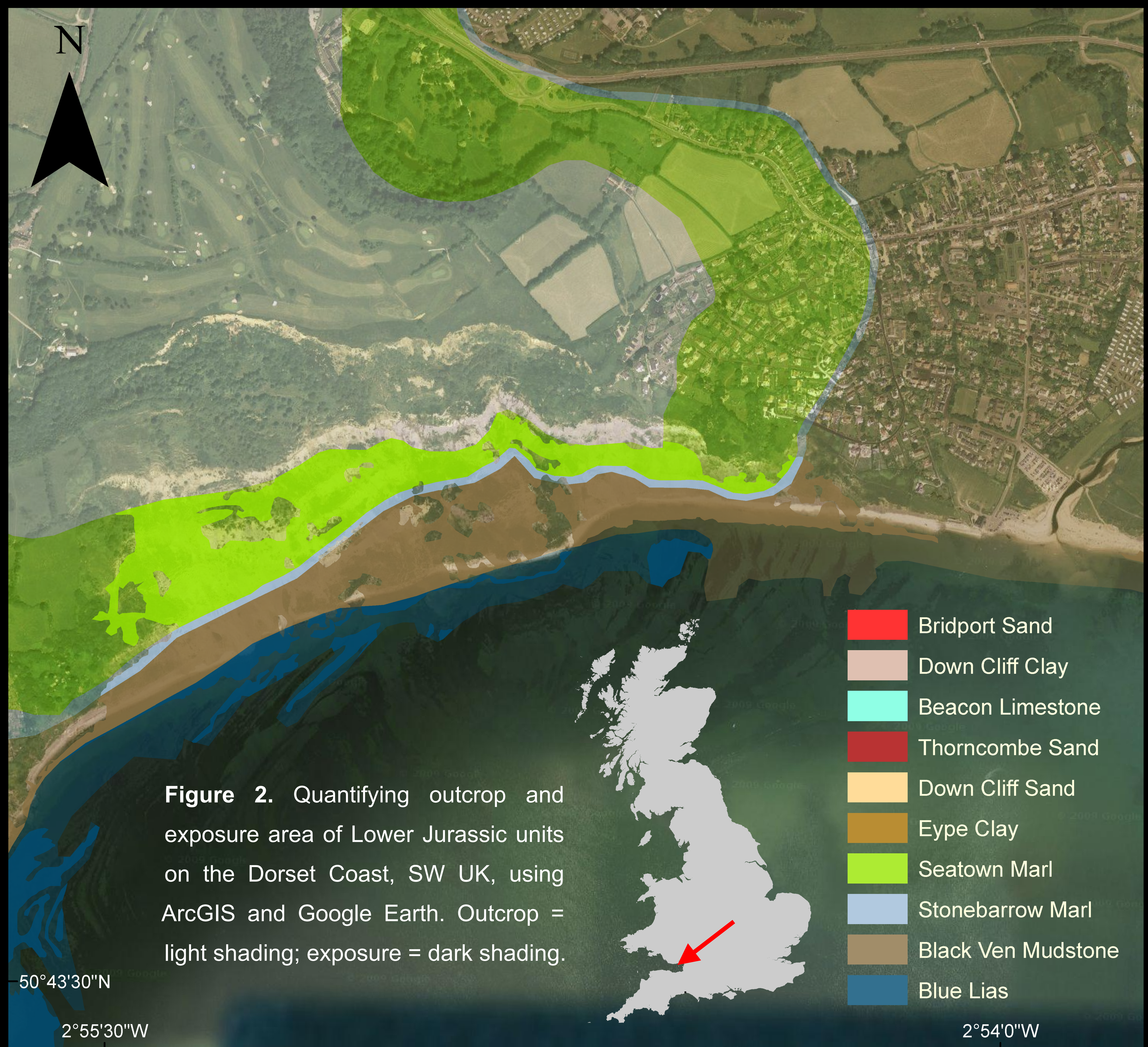



**Figure 2.** Quantifying outcrop and exposure area of Lower Jurassic units on the Dorset Coast, SW UK, using ArcGIS and Google Earth. Outcrop = light shading; exposure = dark shading.

## 2. Testing sampling proxies

Commonly used sampling proxies such as outcrop area and formation counts are rarely tested as to how well they represent the amount of rock available for paleontologists to sample from.

Dunhill (2011, 2012) used GIS and remote sensing (Google Earth) to compare rock outcrop (geologic map) area and rock exposure area (the amount of rock visible at the Earth's surface) in areas of the USA, Australia, and the UK. It was shown that there is limited to no correlation between outcrop and exposure area in the study areas (Fig.1) (Dunhill 2011, 2012). The same results were obtained for correlations between formation counts and exposure area (Dunhill 2011). This suggests that outcrop area is not always a good proxy for the amount of rock available for paleontologists to sample from. The proportion of exposed rock is controlled by many factors that are independent from outcrop area, such as proximity to the coast, elevation, bedrock age and lithology, and land use (Dunhill 2011, 2012).

Data from the Triassic and Jurassic of the UK suggests that sampling proxies representing different aspects of sampling (i.e. rock volume, accessibility, worker effort) do not correlate well with one another (Dunhill *et al.* 2012abc). This suggests that singular sampling proxies are not adequate for identifying the presence of, or correcting for, bias in the fossil record. It is, therefore, preferable to consider multivariate sampling proxy models, where the effects of combinations of proxies representing different aspects of sampling can be assessed with regard to paleodiversity (Dunhill *et al.* 2012c).

**Figure 4 (right).** Sampling proxies representing the accessibility of sedimentary rock; **A**. Number of quarries; **B**. Coastal outcrop area.

## 3. Developing new sampling proxies

The use of GIS and remote sensing has facilitated the development of new, precise sampling proxies to be used in local and regional scale case studies. The combination of GIS and remote sensing has allowed for the capture of rock exposure area in local scale case studies, giving a more accurate representation of the amount of rock available for sampling (Dunhill 2011, 2012; Dunhill *et al.* 2012a) (Fig. 2). Digital terrain models can also be produced to account for variations in topography (Fig. 3). However, in a local scale case study of the Lower Jurassic of the Dorset Coast (Southwest England), neither outcrop area or exposure area, even when modelled on 3D surfaces, correlated well with paleodiversity, suggesting that rock volume or accessibility are not driving apparent diversity (Dunhill *et al.* 2012a).

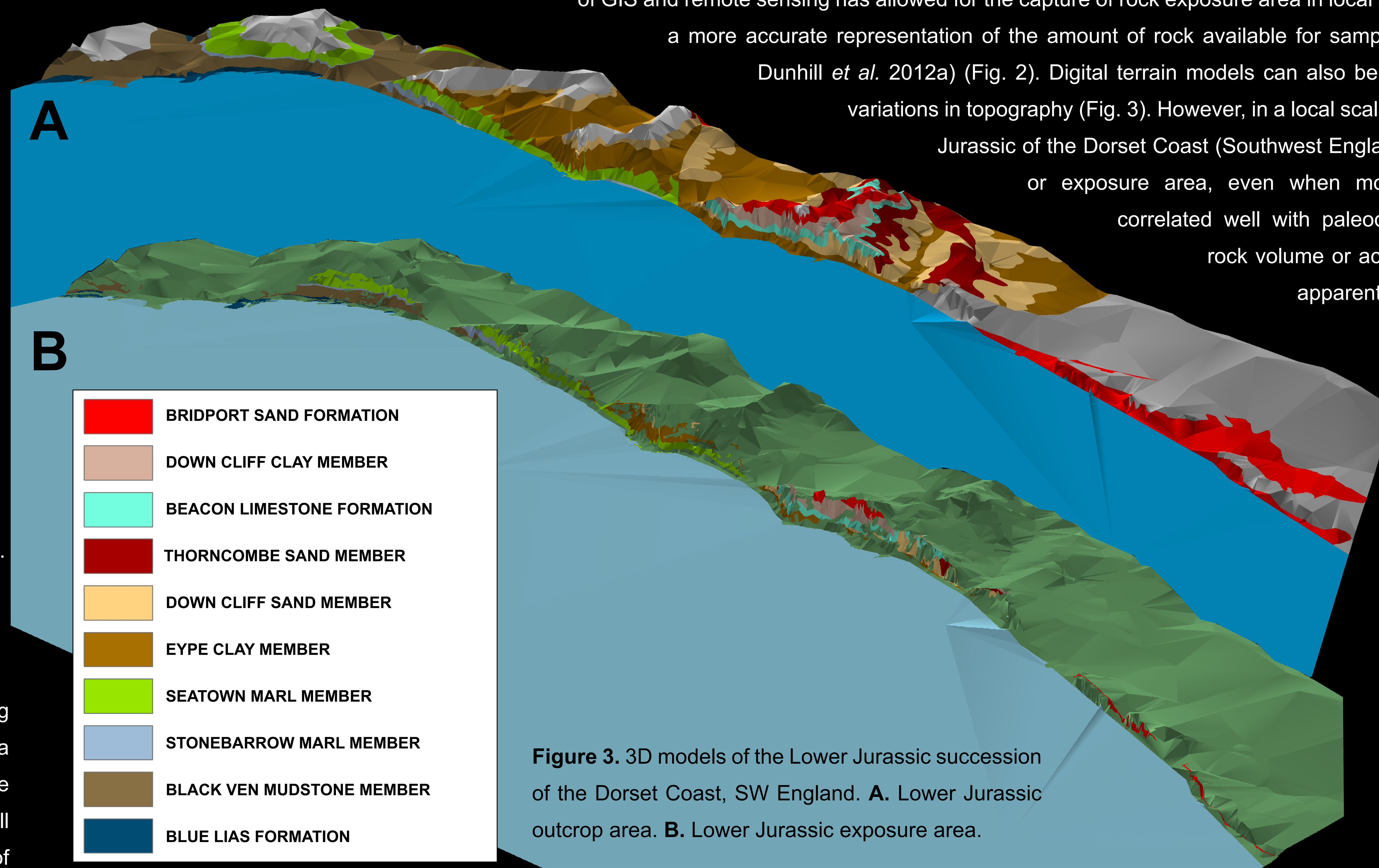
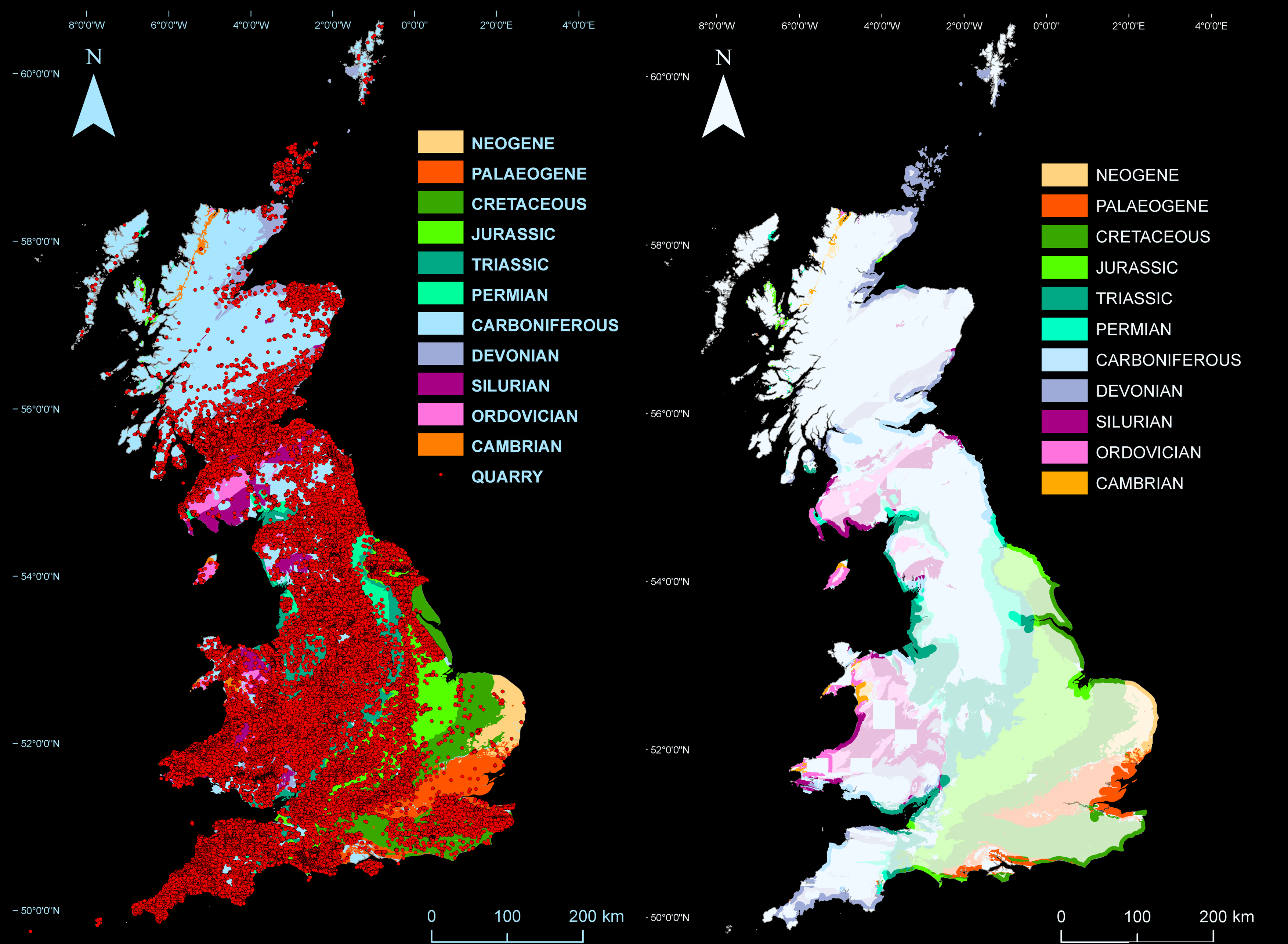



**Figure 3.** 3D models of the Lower Jurassic succession of the Dorset Coast, SW England. **A.** Lower Jurassic outcrop area. **B.** Lower Jurassic exposure area.

GIS can be used to manipulate large spatial data sets, such as the digital geologic maps and quarry databases of the British Geological Survey. Measures of quarry numbers and coastal outcrop areas have been used as sampling proxies in studies of the British Triassic and Jurassic of the UK (Dunhill *et al.* 2012abc) (Fig. 4).





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Dunhill, A.M. (2011) Using remote sensing and a GIS to quantify exposure area in England and Wales: Implications for paleodiversity studies. *Geology*, **39**, 111-114. Dunhill, A.M. (2012) Problems with using rock outcrop area as a paleontological sampling proxy: Rock outcrop and exposure area compared to coastal proximity, topography, land use and lithology. *Paleobiology*, **38**, 840-857. Dunhill, A.M., Benton, M.J., Twitchett, R.J., Newell, A.J. (2012a) Completeness of the fossil record and the validity of sampling proxies at outcrop level. *Palaeontology*, **55**, published online. Dunhill, A.M., Benton, M.J., Newell, A.J., Twitchett, R.J. (2012b) Completeness of the fossil record and the validity of sampling proxies: a case study from the Triassic of England and Wales. *J. Geol. Soc. Lond.*, in press. Dunhill, A.M., Benton, M.J., Twitchett, R.J., Newell, A.J. (2012c) Correcting the fossil record: sampling proxies and scaling. *PNAS*, in review.


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