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Assessing geoheritage significance in studies of palaeoecology – the need to address biocoenoses, thanatocoenoses, biodiversity, palaeo-biodiversity, and quantification

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Assessing the geoheritage significance of fossil-bearing sites and those that portray palaeoecological assemblages requires robust comparisons. However, there are difficulties in undertaking comparisons because, generally, there have not been robust and systematic methods worldwide in describing quantitative abundances of fossils, *i.e.*, the degree to which sites are fossiliferous, or how diverse fossil assemblages are, or whether fossil assemblages are biocoenoses or thanatocoenoses.

To date, descriptions of the contextual setting of fossils and their relative abundance(s) have been uneven. Palaeontologists specialised in a particular fossil group may have focused on a fossiliferous horizon or have collected specimens from poorly fossiliferous formations. In terms of quantitative data, in taxonomic descriptions, palaeontologists may not have described the abundance of the target fossil(s) under study within that formation, nor have considered the diversity or abundance of other fossils therein. Many fossiliferous formations and fossils were described before the discipline of geoheritage and its need for comparative assessment were developed. Much of paleontology still is at a stage of taxon identification, and palaeoecologists and modern ecologists share similar difficulties in defining and describing areas of high biodiversity because a full species list and relative abundances of taxa are absent.

Modern concepts of biodiversity and its numerical determination, ideally, should be transferable to the fossil record if levels of (palaeo-) diversity and levels of significance are to be established. But there are a number of obstacles needed to be overcome if robust comparisons between palaeoecologic units are to be made. The following method has been developed as a systematic comparative assessment of fossil assemblages for their geoheritage significance.

The first step is to determine whether the units under comparison are approximately the same age. The second step is to determine whether the fossil assemblages are biocoenoses or thanatocoenoses. For biocoenoses, comparisons between fossil assemblages can readily be made, and differences can readily be appreciated as being underpinned by different palaeoenvironmental settings or as reflecting palaeo-biogeographic distributions. For thanatocoenoses, comparison of fossil assemblages is made more difficult, as often there is mixing of fossils in different proportions from various environments and ages (*e.g.*, endogenic fossils *versus* exogenic fossils, or even *remanié* fossils). At best, if there is not a major input of *remanié* fossils, thanatocoenoses and mixed thanatocoenoses represent gamma diversity. Separating biocoenoses from thanatocoenoses in the first instance requires a multidisciplinary approach involving careful examination of fossils in the assemblages using growth positions, encrustations, ichnofossils, and other criteria, determining the environment of deposition of enclosing sediments, and thin section determination of the nature of the fossils in terms of diagenesis and transport. Thirdly, axiomatically, a full taxonomic inventory is required - from the macrofossils to the fragmented fossils to the microfossils. Thereafter, following established techniques in modern comparative ecology and biodiversity, fossil assemblages need to be studied quantitatively or, at the least, semi-quantitatively. This involves quantification using quadrats and nested quadrats according to the scale of fossils. In this

paper, examples of assessments of palaeodiversity in palaeoecological studies are provided for Ordovician coral diversity (as gamma diversity), Ordovician benthic assemblages (as alpha diversity), and Quaternary assemblages from Leschenault Inlet estuary and Canning Coast and, in the Perth Basin, the Pleistocene seagrass bank to beach sequence at Tims Thicket, and fossil fauna of Pleistocene rocky shores at Muderup Rocks.

