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A keyed classification of natural geodiversity for land management and nature conservation purposes

Jason Bradbury *

Tasmanian Department of Primary Industries, Parks, Water and Environment, GPO Box 44, Hobart 7001, Australia

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ABSTRACT

Application of the geosciences to land management and nature conservation is retarded by lack of a systematic classification encompassing the entirety of geodiversity. The system suggested here attempts to draw together the many existing sub-disciplinary geoscientific schemes into an overarching framework, whilst allowing their continued use for detailed differentiation of rocks, landforms and soils. It is essentially genetic and based upon reasonable inference of formative process rather than description of material, form or age. It recognises six fundamental classes according to the scale and physico-chemical conditions prevailing during the substantive creation of any aspect of geodiversity. Those classes are: (1) biogenic forms and palaeobiota, (2) offshore sedimentary, (3) non-volcanic igneous, (4) chemical, (5) tectonic and (6) surficial. Within the hierarchy classes are subdivided into themes and then types, for example class igneous, theme intrusive, type felsic or class surficial, theme glacial and cryogenic, type depositional. Twenty-five themes are suggested, encompassing 81 types. A systematic key to type level classification is provided. A fourth level of classification termed element allows more descriptive interface with the multitude of established geoscientific conventions. Geological age provides a fundamental modifier and distinction between active geomorphic process and a record of similar events progressively more lithified with age. The classification is intended principally to assist the identification of a comprehensive and representative geoconservation estate and to facilitate comparison of like objects for significance assessment. The considerable geodiversity of the Australian island state of Tasmania is tabulated by way of example.

1. Introduction

Land management requires an understanding of the land to be managed. The geosciences may provide some essential information however natural geodiversity includes a planet-sized range of rock, terrain and soil forming process and product. An abundance of geoscientific foci, conventions and specialist vocabulary all potentially hinder effective communication between geoscientists and land managers or others lacking "geo-literacy" (Stewart and Neild, 2013). Absence of a comprehensive and systematic classification (Houshold and Sharples, 2008) is here regarded critical to many land management problems. These range in scope from the tenure unit scale to comprehension of the changes characterising entry to a proposed (Crutzen, 2002; Steffen et al., 2011) Anthropocene epoch. Land management is here regarded a broad task, ranging from land use and development planning to oversight of on-ground works. Its varied contexts include urban development, agriculture, forestry, mining, transport and other infrastructure like hydro or wind power development, outdoor recreation and nature conservation. Effective and sustainable land management aims to minimise or mitigate the adverse effects of human land use.

Regardless of context, land managers require some awareness of active geomorphic process and potential hazard; for that reason alone this classification of geodiversity focuses upon operative process(es) and is therefore more genetic than descriptive. By way of example, 'a linear hillock comprised of well sorted and rounded fine sand' may be an adequate material description of a dune but adding the genetic phrase 'wind-blown' provides essential process information. Haskins et al. (1998) noted that "it is desirable that a geomorphic classification system be based on geomorphic process in order to associate related landforms and processes and to define linkages". That is especially relevant to landscape scale ecosystem analysis (Gray et al., 2013) and is here regarded a significant benefit of the genetic approach. Geoscientists must often infer process from material, fabric or form rather than direct observation

* Tel.: +61 0419 886 572.
E-mail addresses: jason.bradbury@bigpond.com, jason.bradbury@dpipwe.tas.gov.au

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of activity. However we can usually be certain of the basic mechanisms that produced an organosol, limestone cave or metamorphic rock for example, despite an almost bewildering array of possible form or fabric in the resultant products.

Some prior classifications for geoconservation purpose have focused on management aims, making a fundamental distinction between exposure and integrity sites (Gray, 2004; JNCC, 2004; Prosser et al., 2006). Although useful in regard to management of threats that approach does not greatly assist comparison of similar sites or evaluation of their geoconservation significance. That requires something more descriptive of site characteristics. However descriptive classifications (e.g. Grimes, 1995; Soutberg, 1990) have failed to complete coverage of the full range of geodiversity, despite in some instances naming hundreds of different rocks and landforms. Others have been designed largely around a certain limited area, the 'blocks' of the British Geoconservation Review for example are intended to ensure equal consideration of "the different aspects of Earth science as seen in Britain" (Ellis, 2011). Between management oriented and descriptive extremes a mixed approach is considered undesirable as that may lead to a confusing inconsistency of the criteria used for classification. Other classifications, such as Ruban's (2010) 21 types of geosites, appear based more upon geoscientific practice (like stratigraphy) than geodiversity itself.

Table 1
Potential threats to geodiversity. These may dictate management requirements but are here entirely separated from classification of geodiversity itself.

Disturbance category	Subtype	Definition	Examples
Ground disturbance (including cave, riverbed, lakebed or seabed)	Trampling or feral invasion	No tools used or no specific intent to cause ground disturbance	Diffuse or directed pedestrian traffic, dune surfing; legal use of navigable waterway, existing bike or 4WD track. Rabbits, lyrebirds, carp, livestock.
	Residential or track work scale	Specific intent to cause ground disturbance using tools or machines operated by handles. Use of a machine with seat but not one specificly designed to cause ground disturbance	Spade, crow bar, rotary hoe, power barrow, ditch witch; off track mountain bike, trail bike or 4WD; wake boarding
	Commercial scale	Earthworks of a scale normally covered by *routine* council, water authority, forestry or similar planning approval process (excluding quarrying and mining)	Dingo, bobcat, backhoe, grader, loader, tipper, small excavator; building and plumbing permits, private 4WD track, small farm dam, snigging, ploughing; minor subdivision, golf course or ski slope development
	Industrial scale	Earthworks that of themselves might be expected to require specific council approval or which represent a significant component of a project requiring approval at state or federal level.	Drill and blast, many hours with a large machinery (excavator, dozer, off-road dump truck, scraper, dredge); new roads or substantive upgrades, quarrying, large water storage or diversion, major reticulation trenching, harbour training walls, mining
Collection	Prospecting or scientific collection	Hand tools used	As per prospecting licence or scientific collection permit
	Significant illegal collection	Targeted illegal collection with or without use of tools or machinery	Unpermitted collection for landscaping, construction, commercial or other purpose
Concealment	By development	Significant reduction in opportunity to observe a site of geoconservation significance	Covering, burial, resurfacing, landscaping, inundation
	By rehabilitation works or regrowth at exposure sites	Significant reduction in opportunity to observe a site of geoconservation significance	Jute mesh, hydromulch, unassisted revegetation of exposure
Disturbance of vegetation	Minor physical disturbance	Piecemeal physical vegetation disturbance other than by fire	Mosaic clearing, firebreak, selective logging, grazing; less than 10% structural change to affected communities
	Substantive physical disturbance	Any extensive physical vegetation disturbance except by fire	Broadacre land clearance, clearfell and most variable retention logging, pasture improvement; greater than 10% structural change to affected communities
	Weed invasion	Change to geomorphic process caused by exotic species	Marram, Spartina
Fire	Small	Fuel carried to fire	Campfire, bonfire
	Large	Fire carries to fuel, intensity or frequency other than that implied by site vegetation or soil	Cool controlled burn, hot controlled burn, wildfire
Catchment effects (on site or remote)	Hydrological modification	Change to hydrological regime affecting local, downstream or remote geomorphic process	Regulation, diversion, extraction, flood control, irrigation, drainage
	Water quality effects	Change to water quality affecting local, downstream or remote geomorphic process	Acidification (e.g. oxidation of acid sulphate soil), eutrophication, oiling; release of chemically labile sediment (e.g. tailings)
	Change to sediment budget	Change to sediment budget affecting local, downstream or remote geomorphic process	Activities causing accelerated erosion or deposition
Coastal engineering	Small scale	Private landholder works within the littoral or dune zones, typically uncoordinated	Ad hoc works including shore protection, boat ramps, jetties and the like
	Engineered works	Co-ordinated coastal zone works by multiple or public landholders	Sea wall, training wall, breakwater, causeway, dredging, outfall
Climate change	–	Climatic effects on geomorphic process beyond strictly local control	Sea level rise; changed rainfall, storm or fire regime; alpine zone retreat
Access	–	Threat due to increased ease of access	New or upgraded track, road or bridge, published site description
Other	–	Disturbance to sites of geoconservation significance by means not described above	Driftwood salvage, toppling of perched erratics, microbiological contamination, climbing bolts, change to cave atmosphere