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ESEX Commentary

Virtual globes: a catalyst for the re-enchantment of geomorphology?

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Baker and Twidale (1991) bemoaned a perceived loss of enchantment from the discipline of geomorphology, arguing that practical and philosophical impediments were thwarting attempts to achieve a satisfying understanding of landforms and their genesis. Other concerns for the status and future of the discipline have been voiced subsequently, most recently in this forum (e.g. Church, 2005; Summerfield, 2005a), and have highlighted challenges such as the relationship of geomorphology to cognate disciplines, difficulties in reconciling teaching and research needs, the balance between pure and applied studies, and the undertaking of landscape studies by researchers from outside the traditional geomorphological community. The purpose of this commentary is not to deny these challenges but to echo Summerfield's (2005a) cautiously upbeat tone, by proposing that a more positive development is the recent launch of virtual globes that vastly increase the availability of digital imagery of the Earth's surface, and thus provide an opportunity for the re-enchantment of geomorphology.

Virtual Globes

Virtual globes such as Google Earth and NASA's World Wind combine topographic representations of the Earth's surface with satellite imagery. Using simple controls, one can zoom from altitude to any natural or urban area, and using a combination of zoom, pan and tilt, examine the terrain at different scales from vertical or oblique, three-dimensional (3D), perspectives. Google Earth has one layer of relatively recent (last three years) satellite imagery stitched together from a variety of commercial sources, whilst World Wind has multiple layers of satellite imagery (e.g. LandSat 7, SRTM, MODIS), as well as topographic maps for the United States. Both programs have higher resolution imagery for some cities and areas of North America and western Europe. Images are fully georeferenced, with options to display relevant coordinates, spot elevations and place names. These facilities have long been available in expensive GIS software packages, but the basic versions of virtual globes are available free on the Internet, can be downloaded and installed in a few minutes, and will run smoothly on most modern computers with a fast internet connection. Thus, with minimal technical ability and a few mouse clicks, virtual globes can bring the varied geomorphology of Earth into one's office or home, and associated animations and overlays can be used to visualize landscape-scale events such as hurricanes, wildfires, floods and dust storms. Virtual globes for other planetary bodies such as the Moon and Mars are available as add-ons for World Wind, and interactive image mosaics are also available via Google Mars and Google Moon. Unsurprisingly, virtual globes have been capturing the imagination of scientists and laypeople alike; in its first week on the web (late summer 2004), 100 000 users downloaded World Wind (NASA, 2004), and millions more have downloaded virtual globes since. World Wind is an open source program, enabling users to contribute their own modifications, and Google Earth allows user modification within certain pre-defined parameters. As reported in *Nature* (Butler, 2006; Nourbakhsh, 2006), researchers in other disciplines have already seized upon the potential of virtual globes to display a variety of spatial data in order to enhance basic scientific and applied work. No doubt many geomorphologists have also considered the possibilities; indeed, when a colleague

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(T.S. McCarthy) introduced me to Google Earth during a visit to Johannesburg last summer, its potential for geomorphological research, teaching and outreach immediately seemed considerable, as outlined below.

Potential Use of Virtual Globes in Geomorphology

Geomorphological research involves a variety of approaches, including field mapping and monitoring, laboratory analyses, physical modelling and numerical modelling. In some cases, virtual globes may usefully supplement these approaches. In particular, by enabling 3D terrain visualization, and by explicitly focusing attention on issues of spatial pattern and scale, they may provoke hypotheses about landscape form and process that can be investigated further using one or more approaches. They may aid fieldwork planning, particularly in terms of sampling design, and local field observations and measurements can be placed more effectively in their broader spatial context. Without virtual globes, similar attempts to assess these spatial issues are often possible only through purchase of aerial photographs or satellite imagery, which are sometimes difficult to source, are often expensive, have fixed resolution and perspective, and are physically unwieldy if large areas are being considered. The advantages of virtual globes in terms of ease-of-use and time saving are clear. For instance, researching river pattern variability across central Australia once took weeks of sifting through aerial photographs in storerooms, but using the spatially searchable, interactive interface of virtual globes, this can now be accomplished more effectively in a few afternoons from my office. Similarly, researching gully distributions in South Africa previously has been hampered by limited aerial photograph coverage or mapping inconsistencies between topographic sheets, but gully locations can now be determined with ease, thus providing an enhanced knowledge base from which to hypothesize about controlling factors. Ideas can be discussed more effectively with distant colleagues by supplying grid references relating to landscape features that they can view with a few mouse clicks on a virtual globe. Reviewers of papers based on some types of field-based research will also benefit, for they can now view the study area, improving their ability to visualize the landforms being described, and perhaps enabling them to challenge interpretations of data in ways not possible previously.

For teaching and outreach, the power of 3D visualization and spatial awareness provided by virtual globes cannot be underestimated. Even the most uninterested student finds it hard not to pay attention during oblique fly-overs of distinctive landscapes such as the dunefields and playa complexes of the Simpson Desert, the Grand Canyon of the Colorado River, the glacial landscapes of the European Alps, or the coastal scenery of New Zealand's Fiordland. Unfamiliar landscapes can be brought into the lecture room in ways that are simply not possible with static slides or photographs taken from fixed perspectives, and familiar landscapes can be seen from new perspectives, provoking more informed contemplation about processes and controls. Key geomorphological concepts, such as scale-dependence of controls, can be illustrated by examining regions or features at different scales. For example, in some sand seas, virtual globes can rapidly demonstrate that at large spatial scales, linear dune orientations tend to be related to regional air circulation patterns, but at smaller scales, other factors start to assume greater importance, with dune orientations commonly adjusting in response to wind and sand transport changes resulting from local topographic forcing. Furthermore, as some researchers have long suggested (e.g. Baker, 1993), imagery available for other planetary bodies can be used to enhance understanding of Earth's processes and landforms. For instance, using virtual globes to view heavily cratered regions of the Moon or Mars immediately begs the question as to why craters are less numerous and less well preserved on Earth, which leads on to consideration of the role of plate tectonics in recycling large parts of the Earth's crust, and the influence of subaerial processes on landscape denudation. Innovative use of such approaches in teaching and outreach can only enhance appreciation of geomorphology.

Limitations of Virtual Globes in Geomorphology

Virtual globes are not without limitations. For many (possibly most) geomorphologists, the potential research advantages may appear trivial, so perhaps their value is more for teaching and outreach. With the present generation of virtual globes, satellite image quality is variable from area to area; spatial resolution is often sufficient for detailed examination only of macro-scale geomorphological features, and images are often several years old and may not have been taken at optimum times for geomorphological analyses (e.g. when high water levels obscure some landforms). Quantitative measurements of key parameters (areas, slopes) are not possible without recourse to additional software and digital data sets (e.g. DEMs). There is also the risk, common to existing remote sensing imagery and GIS software, that virtual globes will simply be used to generate visually appealing imagery without any corresponding advancement in the understanding of geomorphological process and form, particularly because the vital fourth dimension (time) is missing. Nevertheless, the ease of use of virtual globes may well encourage researchers to explore more

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powerful, analytical GIS techniques (Butler, 2006) and, coupled with developments in other areas of the discipline (e.g. increasing use of cosmogenic isotope analysis to quantify process rates and landscape denudation rates), virtual globes can only help promote the recent heightened level of interest in macro-scale landform development outlined by Summerfield (2005a, b). With potential for further technical developments (e.g. higher image resolution, more frequent image updates), and incorporation of innovative visualization of environmental phenomena relevant to geomorphological processes (e.g. 3D fly-bys of weather systems; Butler, 2006), virtual globes can only benefit the discipline.

Enchantment, Disenchantment, Re-enchantment?

'Enchantment' in geomorphology could be defined in various ways but surely involves stimulating interest and excitement in landscape form, process and change, and provoking the all-important reflective questions such as 'why?', 'how?' and 'when?'. Baker and Twidale (1991) argued that the Golden Age of the scientific study of landforms was during the late nineteenth century, when curious, even astounding, tropical and arid region landscapes were investigated by scientist explorers more familiar with the humid temperate landscapes of northwest Europe and northeast North America. The creative thinking stimulated by these new landscapes led to theory development that expanded and improved explanations for already-familiar landscapes. As the twentieth century progressed, however, fascination with landscapes was gradually replaced by a sense of disenchantment as geomorphology tended to overemphasize methodology, either for theoretical abstraction or 'objective' measurement, and geomorphological study became more remote from the realities of the Earth's surface that constitute its *raison d'être*. Baker and Twidale (1991) provided their prescription for the 're-enchantment' of geomorphology, in particular arguing that there was a need for a new intimate association between the scientist and landscape, unfettered by overly restrictive theorizing, that would facilitate identification of anomalies in landscapes and formulation of 'outrageous' hypotheses of causation. They cited fringe areas of the discipline (planetary geomorphology, tectonic geomorphology, study of ancient palaeosurfaces) as examples of where some of the most exciting geomorphology is being conducted.

For many geomorphologists, Baker and Twidale's (1991) prescription undoubtedly continues to be regarded as unpalatable or unnecessary. Outside the aforementioned fringe areas, relatively few geomorphologists have taken the medicine, instead preferring to focus study efforts on more detailed physics-based or mathematical treatments of processes, commonly (but not necessarily) at smaller spatial and shorter temporal scales. Pluralism in study approach and focus should be regarded as as a sign of a healthy, active discipline rather than as a sign of division, although clearly greater efforts are needed to encourage interaction between communities of researchers working at different scales if the discipline as a whole is to reap the benefits (e.g. Summerfield, 2005b). If one accepts that the ultimate goal of geomorphology is to understand the present spatial distribution and interrelationships of Earth surface phenomena at different scales, and to provide explanatory accounts of landscape development through time (cf. Baker and Twidale, 1991), then emphasis on phenomena over larger areas and at longer timescales must constitute a vital part of this collective effort, and virtual globes can facilitate this. Public interest in Earth's landscapes is high, as evidenced by the popularity of virtual globes, yet the term 'geomorphology', and what the scientific study of landscape entails, is understood by relatively few. By harnessing the power of virtual globes in research, teaching and outreach, can this act as a catalyst for the re-enchantment of geomorphology? Will this encourage renewed fascination with landscapes, and thus promote geomorphology as a worthwhile, valid and distinctive study endeavour? Will this lead to more hypotheses regarding landform genesis that could be tested by field, laboratory or modelling approaches, perhaps extending and/or replacing prevailing concepts and theories? Whilst clearly not a panacea, will this help to counter or circumvent some of the challenges that the discipline faces?

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