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Catchment reconstruction — erosional stability at millennial time scales using landscape evolution models

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ABSTRACT

An important part of planning for the rehabilitation of a mine site is the design of stable final landforms for waste rock dumps or spoil piles. Whilst able to be assessed over the short-term (years to decades), the longer term behaviour (centuries to millennia) of such landscapes is not within any meaningful human time frame of observation. Predictive numerical models, therefore, form an important tool with which current landscape behaviour and longer term trajectory can be assessed. However, an important issue associated with the use of models is the ability to assess the reliability and accuracy of the model. Here the SIBERIA and CAESAR-Lisflood Landscape Evolution Models (LEMs) are used to simulate and assess the geomorphic stability of a conceptual rehabilitated landform of the Ranger uranium mine in the Northern Territory, Australia, for a simulated period of up to 1000 years. Utilising both models in this study enabled an independent assessment of likely landscape processes and evolution as well as each model. Results show that SIBERIA and CAESAR-Lisflood produce erosion rates and patterns that are broadly similar. At millennial time scales, short-term processes such as gullying appear to be the dominant erosion features in the proposed landforms and may produce substantial erosion in terms of size and amount of hillslope material eroded and transported downslope. Vegetation was found to have a major effect on the erosion potential of the landform surface. Overall both models produce very similar results.

1. Introduction

Humans have developed technology to modify the Earth surface at scales greater than ever before. In particular, open-cut mining has developed earth moving technology (explosives, excavators, shovels, trucks) that allow whole landscapes to be removed to gain access to a resource. Because of such and similar human action, it has been argued that we have entered the new epoch of the Anthropocene (Brown et al., 2013). However, during and post-mining it is vital that the disturbance be minimised for economic and environmental reasons, and more importantly at the completion of mining the landscape should be restored so that it is ecologically functional and is sustainable with its surrounds.

In the case of open-cut mining (the focus of this study) noneconomic material (waste rock) is removed from the surface to obtain access to the resource (in this case uranium). This results in a large void from which the resource is extracted and a corresponding mound of waste or subeconomic material. In many cases the pit or void is allowed to be left unfilled at the completion of mining as it is uneconomic to back fill the pit, or with a view that in the future it may allow access to currently sub-economic reserves. However, the waste rock from the pit needs to be rehabilitated as a functional, sustainable, and stable environment. In some cases the pit may be filled with waste material that if left exposed may have environmental impacts. This material (in this example, low grade uranium ore and tailings) may be capped with material that is erosionally stable and supportive of vegetation.

The viability of any reconstructed landform requires assessment for its long-term erosional stability. An erosionally unstable landscape may lead to the loss of the most fertile and organic rich component of the developing soil profile. Further, gullies may develop which have the potential to cause deep incisions in into the site allowing rapid erosion and water ingress into the landscape, which may lead to a risk of exposure and transport of contaminated sediment.

Generally, all post-mining landscapes have steeper slopes and longer slope lengths than that of the surrounding undisturbed systems from the increase in volume of material that results from blasting and handling, weathering, and mechanical breakdown especially of fresh rock. In such an environment, the presence of highly erodible unconsolidated material with minimal organic content and the absence of vegetation may result in a landform with high erosion potential Therefore, a newly constructed landscape (even in the absence of gullying) often erodes at a higher rate than the surrounding undisturbed landscape. Correspondingly, the surrounding landscape may

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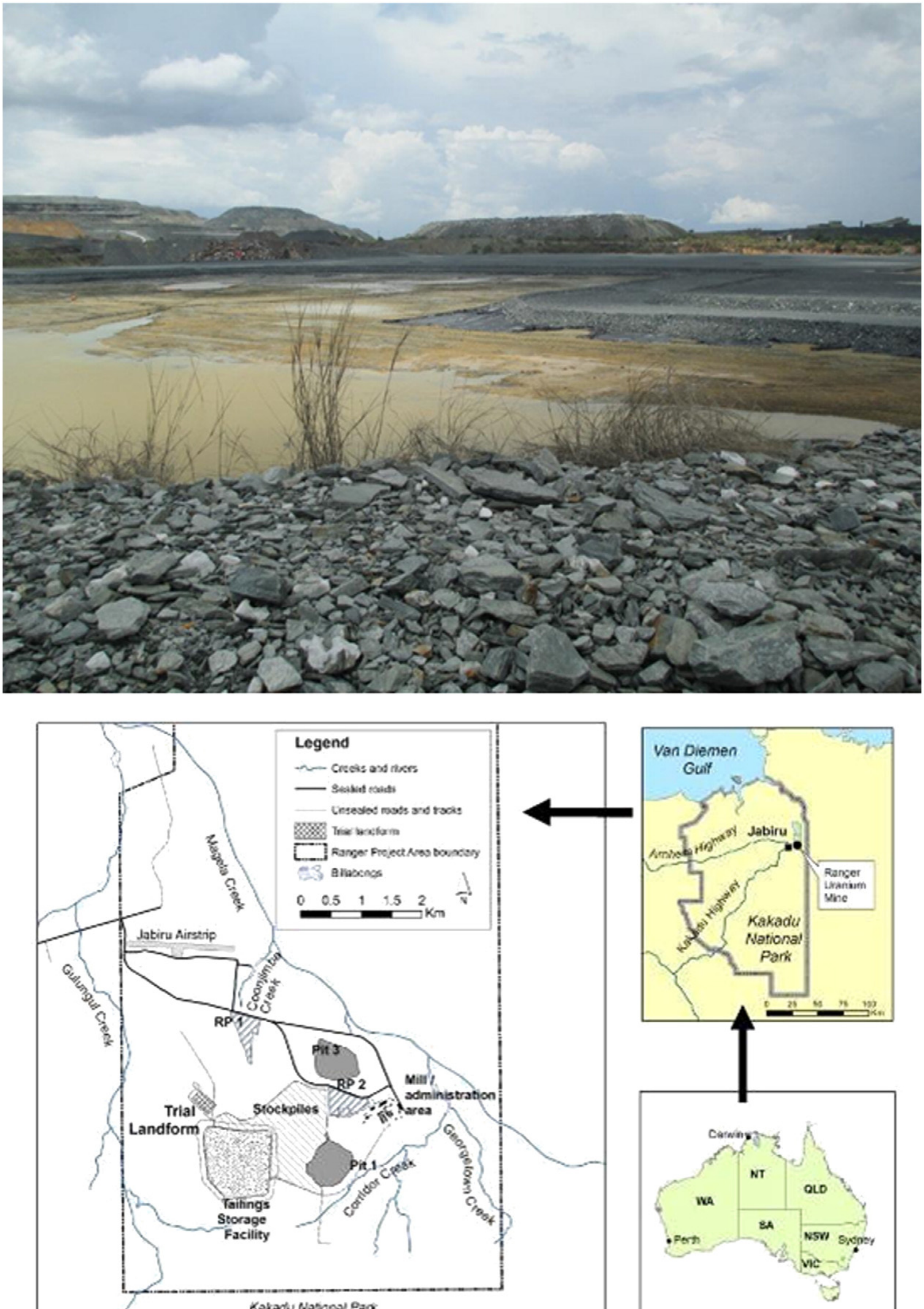

Fig. 1. Pit 1 at the ERA Range mine to provide a measure of scale of the exhumation at the site (top) and location of the study site (bottom).