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Rapid and selective clast weathering on an alluvial fan, eastern Karoo, South Africa

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ABSTRACT

A small alluvial fan formed on the surface of a dry infilled dam in January 2010 as a result of a high-magnitude rainfall and flood event. Gravel and boulder-size clasts in the fan comprised dolerite, mudstones and fine-grained sandstones. Within a month of formation some mudstone gravels had disintegrated due to weathering processes. The fan was investigated four years later and the weathering of different lithologies was categorised and quantified. Almost half of the weathered clasts were completely weathered forming small heaps or spreads of particles <4 mm in size. The majority of these were mudstones. Dolerites, except for those with signs of weathering prior to transport, were almost all unaffected. Rapid weathering of mudstones which underlie small areas of the local slopes helps explain how fine grained materials are transferred from slopes to the valley bottom gullies. The considerable thicknesses of colluvial and alluvial deposits that have developed in the Holocene and now mantle the footslopes and infill valley bottoms, are composed of dolerite and occasional sandstone clasts and fine-grained material derived from rapid and selective weathering of mudstones and sandstones.

1. Introduction

The Sneeuberg uplands in the eastern Karoo rise to 2504 m at Kompasberg (Fig. 1). They are composed of Permian to Triassic mudstones and sandstones of the Karoo Supergroup with prominent doleritic intrusions often underlying the high ground. On the upper slopes of the valleys are extensive outcrops of fine sandstones with occasional mudstone beds of the Katberg Formation (early Triassic). These are underlain by mudstones and sandstones of the Balfour Formation outcropping in the valleys. Dolerite intrusions in the form of dykes and sills outcrop frequently especially on hilltops (Council for Geosciences, 1996; Johnson et al., 2006). The footslopes are thickly mantled with colluvium and alluvial fans with up to 6 m of colluvium in valley bottoms. A typical geological sequence is shown in Fig. 2.

Incision by gullies (dongas) in valley bottoms reveals a sequence of former wetland (vleis) deposits overlying earlier Holocene colluvium and much older weathered boulder-rich deposits of debris flow and fluvial origin (Holmes et al., 2003). Gully incision appears to result from European incursion, settlement and farming of the area and consequent land degradation (Boardman, 2014). The boulder deposits contain severely and partially weathered clasts including large dolerite boulders. Gullies are generally cut to bedrock.

Valleys in the study area are at ca. 1600 m and consequently the area is considerably wetter than many parts of the Karoo with annual average precipitation for 1988–2012 of 507 mm at Compassberg Farm (the gauge was moved downvalley to Lucernvale in 2009) (Fig. 1). The area is in the summer rainfall belt with on average 45% of annual precipitation falling in January to March. Long-term records from nearby towns and farms show little change in annual amounts but an increase in large events and a concentration of rainfall on fewer rain days (Boardman et al., 2010). Very generalised temperature data exists for the area: Schulze (1980) reports summer maxima of ca. 30 °C and winter minima of −10 °C.

The vegetation of the area is typically *Elytropappus rhinocerotis-Euryops annae* shrubland with *Merxmuellera* (now *Tenaxia*) *disticha* tussocks. Around the northern base of Kompasberg is a shrubby variant of Karoo Escarpment Grassland (Mucina and Rutherford, 2006; Dr V.R. Clark, personal communication). The area has been heavily overgrazed in the past resulting in land degradation and the development of gullies and small areas of badlands (Boardman et al., 2003).

The aim of this paper is to examine evidence for rapid weathering of gravel and boulder-size clasts on a small alluvial fan over a four-year period. The precise dating of fan formation provided a unique opportunity to study rates of clast weathering. The selectivity of weathering processes is investigated with reference to available lithologies on the fan. The implications for erosional processes of the rapid and selective weathering are discussed. The paper forms part of a co-operative research project in the Sneeuberg uplands e.g. Boardman et al. (2003, 2010).

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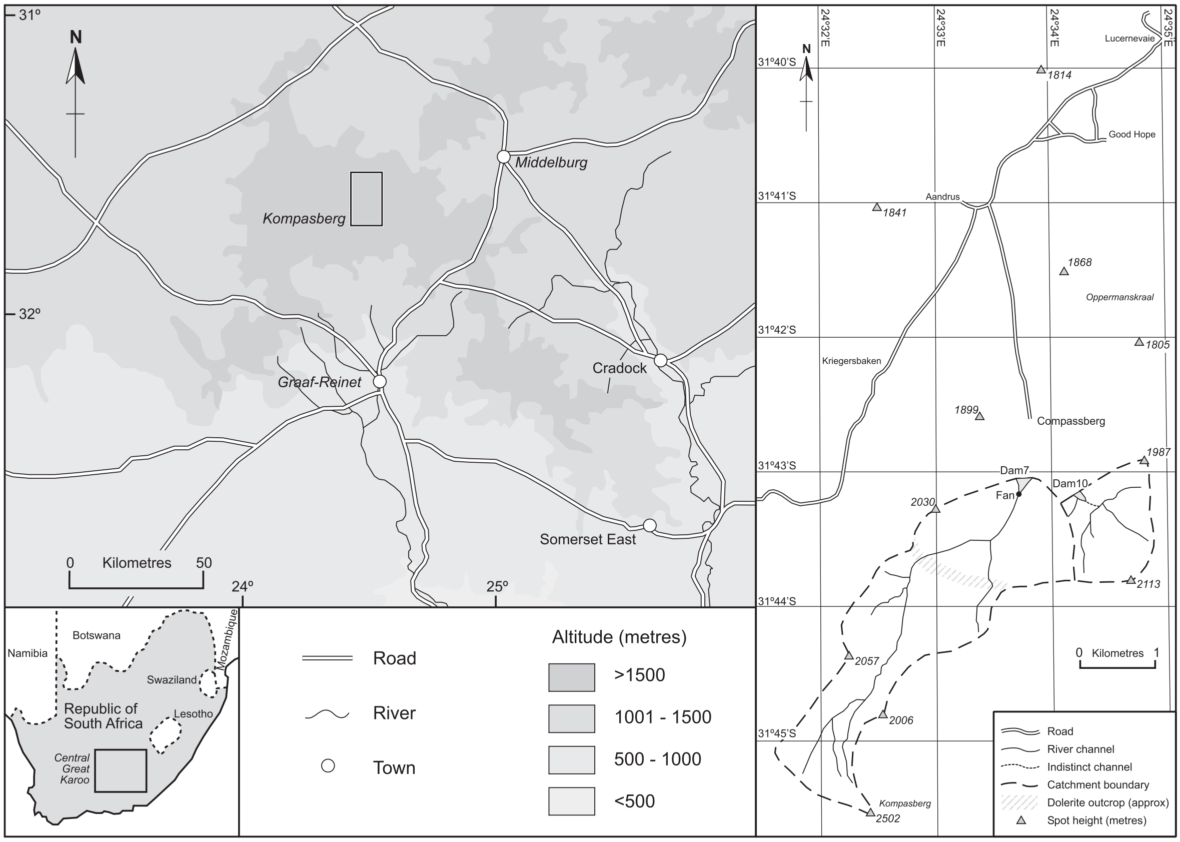

Fig. 1. Location of study site showing fan at head of Dam 7.

2. A flood event and fan formation

The fan at Dam 7 was the result of a localised, high-magnitude storm of 50 mm on 22 January 2010 which also caused serious damage to a dam spillway (Dam 37) and washed away a farm access bridge at Lucernvale (Fig. 1) Some nearby farm gauges recorded >100 mm for the same day (Dr Dave Gaynor, personal communication). The January monthly total of 172 mm was exceptional.

Dam 7 is filled with sediment to the level of the spillway and the earth dam wall was breached in 2000. In January 2010, flow occurred across the floor of the dam and through the breach (Boardman and Foster, 2011). At the upstream end of the dam, a fan formed on the site of previous now vegetated fans. The fan comprised boulders, gravel and sand plus organic debris which lodged behind boulders and shrubs (Fig. 3). Brief reconnaissance of the site on 16 February 2010 revealed mudstone on the recent fan had already weathered to the extent of being broken into small pieces. The fan was formed by flow along a gully (donga) which left a debris line at 1.6 m above the floor where the gully was 13 m wide. Large boulders had been moved to the fan by this event (see below).

Since its formation there has been no sign of flows having impinged on the fan. Low flows routinely take a course around the slightly higher

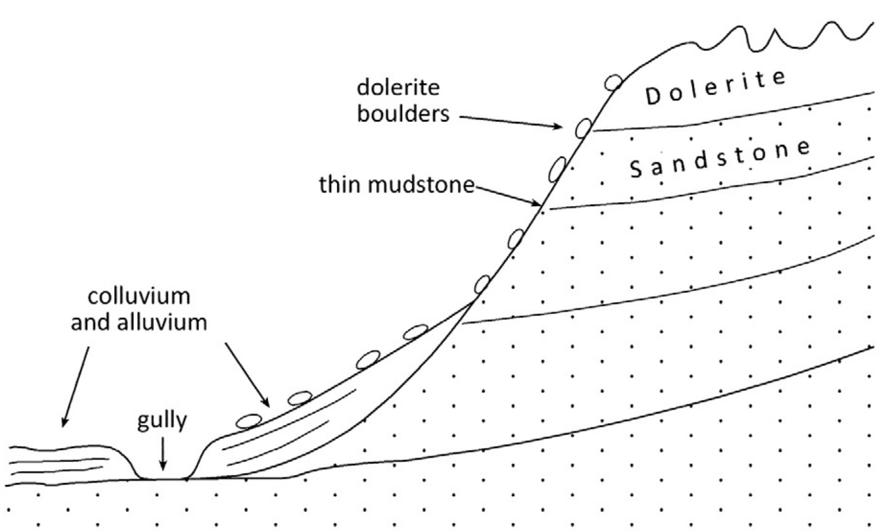

Fig. 2. Diagrammatic representation of geological sequence in the study area.