Figure 1. Basalt cliffs of the Drakensberg Escarpment rise above the typical summer mist. Photo credit: Lon Abbott and Terri Cook.

# The Drakensberg Mountains: Southern Africa's Barrier of Spears

Lon Abbott[1,*] and Terri Cook[2]

**When the Zulu and the Sotho, two Bantu-speaking peoples, migrated into southern Africa from the north around 500 C.E. (Ehret, 1998), they marveled at the precipitous, 1,500-m-high escarpment that marks the southern and eastern edges of the highlands along today's Lesotho–South African border (Fig. 1). Both groups drew on their martial traditions when naming this seemingly impenetrable feature, calling it the "barrier of spears'" in their respective languages. To the Dutch-speaking Boer who encountered the escarpment over a millennium later, it resembled a dragon's back, hence the name Drakensberg in Afrikaans. All these immigrant groups both mixed and clashed with the local, click language–speaking San people, the traditional inhabitants, who have left a 3,000-year legacy of evocative paintings in the natural rock shelters formed by overhangs in the range's Clarens Sandstone (Fig. 2; Witelson et al., 2021).**

The Drakensberg Escarpment's magnificent scenery continues to fuel popular imagination today. South Africans are fond of claiming that the Drakensberg were the inspiration for J.R.R. Tolkien's Misty Mountains, which feature in *The Hobbit* and the *Lord of the Rings* trilogy. Although the comparison is apt, the author, who was born in Bloemfontein, South Africa, emigrated at the age of three and said he had few memories of the continent. The Drakensberg did, however, inspire a

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twenty-first-century cultural icon: Wakanda, the mythical country featured in director Ryan Coogler's 2018 Academy Award–nominated film *Black Panther*, which he based on the geography and history of Lesotho (Jones, 2018).

## HOW DO GREAT ESCARPMENTS EVOLVE? THE DRAKENSBERG AS A TESTING GROUND

The Drakensberg constitute the most dramatic section of the much longer Great Escarpment, whose ramparts form a ring paralleling southern Africa's coastline and separate the inland Karoo/Kalahari plateau from the coastal lowlands (Fig. 3). Such inland plateaus flanked by escarpments are common features of the passive continental margins surrounding the Atlantic, Indian, and other ocean basins that formed during breakup of the supercontinent Pangaea. These features are called elevated passive continental margins (EPCM), and most geologists consider them an enduring legacy of continental rifting (e.g., Blenkinsop and Moore, 2013).

Ever since the classic work of Lester King (1947), the Drakensberg Escarpment has played a prominent role in scientists' attempts to decipher how EPCMs evolve. The Drakensberg Escarpment currently lies 200 km from the coast, and it isn't associated with major faults. But King, an early supporter of continental drift, concluded that the escarpment originated along Mesozoic coastal faults when Gondwana split apart. He argued that the escarpment retreated landward, a process called backwearing. That was a departure from William Morris Davis's (1909) then-preeminent downwearing model, which emphasized vertical erosion. Despite their disagreement on mechanism, both Davis and King believed that today's landscapes were produced by multiple cycles of uplift and subsequent erosion. The end result of each cycle was a nearly flat plain, which Davis called a peneplain and King called a pediplain. The number of low-relief surfaces preserved in a landscape equals the number of cycles of uplift that landscape has experienced.

Subsequent researchers have built on King's (1953) ideas, producing the "classical" cyclic model of southern African landscape development. It calls for three cycles, including major uplift at 2.5 Ma and retreat of the Drakensberg Escarpment at an average rate >1 km/m.y. since the Mesozoic (Partridge and Maud, 1987).

Work in the Drakensberg using cosmogenic radionuclide dating (CRN) and low-temperature thermochronology has been central to a comparatively recent reassessment of the classical model and the tenet that EPCM escarpments retreat inland from the coast. Using CRN dating, Fleming et al. (1999) measured the current escarpment retreat rate at a mere 50–95 m/m.y., an order of magnitude slower than the classical model predicts. Two low-temperature thermochronology studies bolstered the case that the Drakensberg Escarpment did not originate on the coast (Brown et al., 2002; Flowers and Schoene, 2010), and a numerical model (van der Beek et al., 2002) indicated that fluvial erosion quickly erases the rift-generated coastal escarpment. Downwearing then produces a new escarpment (the modern one) along the post-breakup drainage divide.

These results placed downwearing, minus Davis's or King's erosion cycles, back at the forefront of scientific thinking about EPCM evolution. But not everyone agrees that the Drakensberg Escarpment is the result of downwearing (Blenkinsop and Moore, 2006; Roberts and White, 2010). How and when EPCM escarpments form remains an open question; given that the Drakensberg is the type example of this landform, it's a good bet that it will figure prominently in future research striving for an answer.

## ROCKS OF THE DRAKENSBERG: THE KAROO SUPERGROUP

All rocks exposed in the Drakensberg belong to the Karoo Supergroup, a world-class sequence of sedimentary and volcanic rocks that accumulated in the Karoo Basin, which formed in the Carboniferous in response to flexural loading by the Cape Fold Belt Mountains

> THE RANGE'S GEOLOGIC AND GEOMORPHOLOGIC ATTRIBUTES MAKE IT A TESTING GROUND IN THE CONTINUING QUEST TO ANSWER FIRST-ORDER SCIENTIFIC QUESTIONS.

Figure 2. Gudu Falls tumbles over a cliff in the Clarens Sandstone, the uppermost formation in the Stormberg Group. Photo credit: Lon Abbott and Terri Cook.

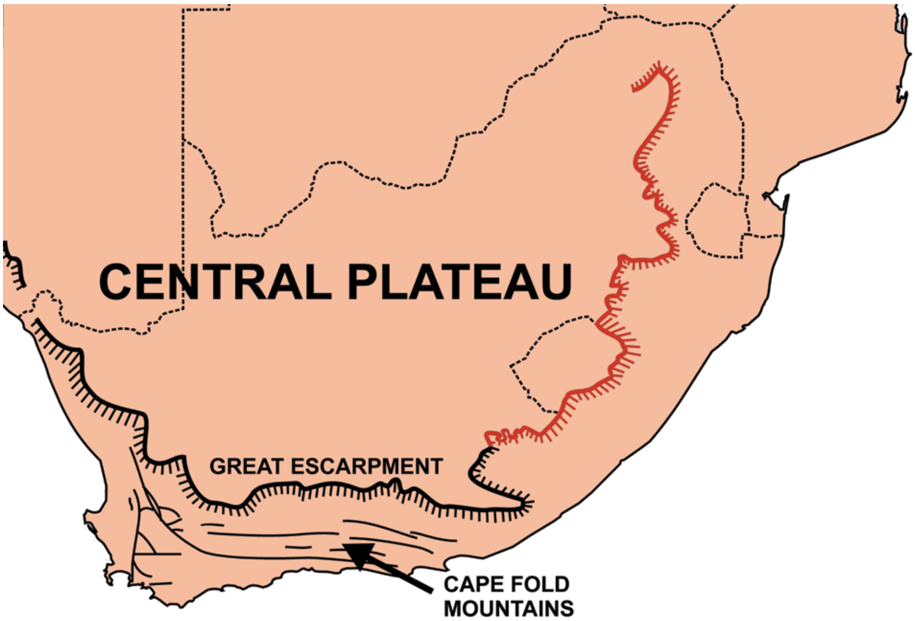


Figure 3. Map of southern Africa showing the high Central Plateau (Karoo/Kalahari Plateau) flanked by the Great Escarpment, shown by the hatched line. The red hatched line delineates the Drakensberg portion of the escarpment. The country of Lesotho is outlined by the dashed black line and the segment of the red hatched line it touches. That is the High Drakensberg. Credit: Oggmus via Wikimedia Commons (https://commons.wikimedia.org/wiki/File:The_Escarpment_and_the_Drakensberg.jpg).

(Catuneanu et al., 2005). The Supergroup consists of a >6-km-thick stack of fossiliferous sedimentary rocks that accumulated between ~300–183 Ma and that preserve excellent records of both the Permian–Triassic and Triassic–Jurassic mass extinction events, two of the "Big Five" extinctions. These are overlain by 1.6 km of Jurassic basalt that erupted from the Karoo Large Igneous Province (LIP); LIPs are Earth's biggest volcanic centers. The Karoo Basin stretches across most of South Africa, and only the two stratigraphically highest of the Supergroup's five groups, the Stormberg and Drakensberg groups, are exposed in the high Drakensberg Mountains.

The 1.5-km-thick Stormberg Group, which is exposed on the lower flanks of the Drakensberg, consists of Triassic to Early Jurassic fluvial and aeolian sediments deposited in an increasingly arid climate. Deposition of the Elliot Formation spanned the Triassic–Jurassic boundary, and it contains an abundant and diverse vertebrate fossil record. That makes it a global standard for study of Mesozoic vertebrate evolution and the Triassic–Jurassic mass extinction event (Bordy et al., 2020). This formation is overlain by the cliff-forming, aeolian Clarens Sandstone (Fig. 2). Erosion of the Clarens produces abundant overhangs, beneath which the San left thousands of evocative paintings, typically in locations where the rock face is irregular. That technique causes the figures to appear as if they are either emerging from the rock or receding into the background. Archaeologists conclude that the San used the rock face as a "veil" that obscures other spiritual worlds from our own; the paintings depict a shaman's out-of-body experiences while visiting other worlds during their spiritual work (Lewis-Williams and Dowson, 1990).

THAT TECHNIQUE CAUSES THE FIGURES TO APPEAR AS IF THEY ARE EITHER EMERGING FROM THE ROCK OR RECEDING INTO THE BACKGROUND.

Clarens deposition ended with the onset of rapid and massive basaltic volcanism in the Karoo LIP (Fig. 1; Catuneanu et al., 2005). Although most of the Clarens Formation was deposited in a sand dune–dominated desert, just before the eruptions began the area became moist enough to support a diverse biota, including gymnosperm trees. Some of the earliest lava flows spilled into streams and lakes, producing pillow basalts. The lava flows carried logs with them, as evidenced by the petrified wood that is preserved among the pillow lavas (Bordy et al., 2021).

## DO FLOOD BASALTS TRIGGER MASS EXTINCTIONS?

Multiple researchers have noted the striking age correlation between the emplacement of LIPs, various indicators of environmental perturbations such as carbon isotope excursions and oceanic anoxic events, and mass extinctions. This temporal correlation has led to the hypothesis that injection of massive quantities of $CO_2$ and $SO_2$ into Earth's atmosphere during LIP eruptions produces massive environmental change that in turn triggers mass extinction (e.g., Courtillot and Renne, 2003). The Karoo LIP is an excellent example of that correlation (e.g., Pálfy and Smith, 2000; Moulin et al., 2011; Sell et al., 2014).

The Drakensberg flood basalts are big, covering 3 million km$^2$, but they are merely the biggest surviving remnant of what was once a much larger basalt plain. The 183 Ma basalt over which Victoria Falls plunges along the Zimbabwe–Zambia border is another remnant, and the contemporaneous dolerite dikes and sills that are abundant throughout southern Africa record a vast area where these lavas were once continuous but subsequently eroded (Marsh et al., 1997). The Karoo LIP erupted immediately before Gondwana broke up, and it also covered portions of Antarctica and Australia in what is called the Ferrar LIP. Together, the estimated volume of the Karoo-Ferrar LIP is a massive 2.5 million km$^3$. The ascending magmas not only carried large quantities of volcanically derived $CO_2$ and $SO_2$ but also oxidized the abundant carbon- and sulfur-rich Karoo Supergroup rocks, generating yet more of these temperature-altering gases (Svensen et al., 2007). Moulin et al. (2011) estimated that Karoo LIP eruption liberated >60,000 gigatons of $CO_2$, enough to affect global climate.

But directly ascribing environmental changes to outgassing from the Karoo or any LIP is tricky and requires ultra-precise dating of both the LIP and the environmental changes. For the Karoo LIP, the combination of stratigraphic observations and magnetostratigraphy with high-precision Ar/Ar and U/Pb dating has enabled geoscientists to approach the necessary resolution (Moulin et al., 2011; Sell et al., 2014; Antoine et al., 2022). Evidence indicates that the Karoo LIP experienced multiple eruptive phases, with the vast majority of the volcanic pile erupted in as little as 250,000 years at ~183 Ma. The first pulse seems to correspond with global cooling and marine regression at the Pliensbachian–Toarcian stage boundary, while the main eruptive event coincides with global warming and oceanic anoxia in the early Toarcian. Sharp carbon isotope excursions testify to the profound ecological disruptions that accompanied both pulses and correspond to the two phases of a second-order mass extinction event (Pálfy and Smith, 2000; Moulin et al., 2011). The ever-higher precision age constraints on the Karoo LIP and contemporaneous environmental effects have made it a prominent test case for the idea that LIP eruptions have triggered most of the planet's profound environmental and biotic crises.

## AN OUTSTANDING EXAMPLE OF AFRICA'S GEOHERITAGE

The Drakensberg possess grand scenery that has nurtured the spiritual life of its inhabitants for millennia and continues to inspire the popular imagination. The range's geologic and geomorphologic attributes make it a testing ground in the continuing quest to answer first-order scientific questions. These characteristics are the very essence of the concept of geoheritage, which the Geological Society of America (GSA) defines as "sites or areas of geologic features with significant scientific, educational, cultural, and/or aesthetic value" (National Academies of Sciences, Engineering, and Medicine, 2021; GSA, 2022).

Protection of landscapes that possess such international geological significance is the goal of UNESCO Global Geoparks, as is ensuring that their protection goes hand in hand with sustainable development that benefits the geopark's inhabitants (UNESCO, 2023). Yet despite Africa's rich geoheritage, only two of the 177 UNESCO Global Geoparks are on the continent, in Morocco and Tanzania. In December 2022, UNESCO conducted a capacity-building workshop on African geoheritage in Kenya. It focused on devising ways to connect Africa's rich geological and cultural heritage to mechanisms that promote regional sustainable development (UNESCO, 2023). We hope this workshop catalyzes the establishment of more UNESCO Global Geoparks in Africa, and we think that portions of the Drakensberg are worth considering as additions to that illustrious list.

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