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From Lesotho basaltic highlands to the Namib Sand Sea: long-distance transport and compositional variability in the wind-displaced Orange Delta

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Sourced as the Nile in distant basaltic rift highlands, the Orange River is the predominant ultimate source of sand for the Namib desert dunes, as proved independently by bulk-petrography, heavy-mineral, pyroxene-chemistry, and U/Pb zircon-age datasets. Additional local entry points of sand do exist at the edges of the desert, and were quantified by comparison with detrital modes and heavy-mineral suites of hinterland-river sediments.
After long-distance fluvial transport, Orange sand is washed by ocean waves and dragged northward by vigorous longshore currents. Under the incessant action of southerly winds, sand is blown inland and carried farther north to accumulate in the Namib erg, a peculiar wind-dominated sediment sink displaced hundreds of kilometres away from the river mouth. And yet changes in sand mineralogy along the way are minor. After a multistep journey of cumulative 3000 km from their source in Lesotho, volcanic rock fragments and pyroxene are found in unchanged abundance as far as the northern edge of the desert. Only locally is volcanic detritus slightly depleted and minor but regular enrichment in quartz and garnet observed, the sole potential effect of prolonged transport or recycling of Tertiary eolianites. Selective comminution of fragile minerals is thus proved unable to substantially modify sand composition in fluvial, coastal, or eolian settings. Mechanical processes have a much greater effect on the morphology of detrital grains, which in Namib dunes appear commonly shaped into nearly perfect spheres. Eolian sorting concentrates denser minerals locally in placer lags, but such effects can be identified and compensated for. This study demonstrates that mechanical breakdown is unable to markedly affect provenance signatures even during long-distance and prolonged multistep transport in high-energy settings. In arid climates, where chemical processes are negligible, high-resolution bulk-petrography and heavy-mineral analyses are thus powerful techniques to quantitatively reconstruct provenance, and to trace sediment sources and dispersal paths over distances up to thousands of kilometres.