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Hydrogeological controls on groundwater recharge in a weathered crystalline aquifer: A case study from the Makutapora groundwater basin, Tanzania

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Drylands (semi-arid/arid regions) represent >35% of the Earth's surface, support a population of around 2 billion people, and are forecast to be increasingly water stressed in coming decades. Groundwater is the most reliable source of water in drylands, and it is likely that the structure and hydraulic properties of superficial geology play a crucial role in controlling groundwater recharge in these regions. However, the spatio-temporal hydrogeological controls on the rates of groundwater recharge, and their sensitivity to environmental change are poorly resolved.

In the Makutapora groundwater basin (Tanzania), an analogue for semi-arid tropical areas underlain by weathered and fractured crystalline rock aquifers, we conducted a series of geophysical surveys using Electrical Resistivity Tomography (ERT) and frequency domain electromagnetic methods (FDEM). Using these data, in conjunction with borehole logs, we identify and delineate five major lithological units in the basin: 1) Superficial deposits of coarse sand (>200 Ω m) 2) Highly conductive smectitic clays (1-10 Ω m) 3) Decomposed pedolitic soils (30-100 Ω m) 4) Weathered saprolite (100-700 Ω m) and 5) Fractured granitic basement (>700 Ω m). We also identify 10-50m wide zones of normal faulting extending across the basin and cutting through these units, interpreted with the aid of analysis of a digital elevation model alongside the geophysics data.

These results are combined with existing long-term hydrological and hydrogeological records to build conceptual models of the processes governing recharge. We hypothesise that: 1) Zones of active faulting provide permeable pathways enabling greater recharge to occur; 2) Superficial sand deposits may act as collectors and stores that slowly feed recharge into these fault zones; 3) Windows within layers of smectitic clay underlying ephemeral streams may provide pathways for focused recharge via transmission losses; and 4) Overbank flooding during high-intensity precipitation events that inundate a greater area of the basin increases the probability of

activating such permeable pathways.

Our results suggest that configurations of superficial geology may play a crucial role in controlling patterns, rates and timing of groundwater recharge in dryland settings. They also provide a physical basis to improve numerical models of groundwater recharge in drylands, and a conceptual framework to evaluate strategies (e.g. Managed Aquifer Recharge) to artificially enhance the availability of groundwater resources in these regions.