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Groundwater resources of the Danakil Depression (northeastern Ethiopia) – hydrogeology in the hottest place on Earth

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The Danakil Depression of the Afar Rift forms part of the N/S-trending Ethiopia-Eritrean arm of the East African Rift System, whereas the western margin of the depression forms part of an active plate boundary between the western Nubian and eastern Danakil tectonic blocks. Dallol (within the Danakil) currently holds the record for the highest average temperature for an inhabited place, with annual average temperatures of ~35-36°C, and an average of ~45°C in summer. The isolated area was initially explored geologically in the late 1960s [1], with recent geological and hydrogeological interest in its NE Ethiopian portion due to easier access, geo-tourism features such as the Dallol thermal field and Erta Ale volcanic range, and potash-ore exploration within the rift basin [2]. Mining of potash (specifically sylvinite) is proposed via solution-extraction techniques, requiring large volumes of water (tens of millions of m^3 per annum), in one of the driest of all hyper-arid regions.

Regional stratigraphy in the NE Ethiopian portion of the Danakil Depression consists of 3 main divisions (from youngest to oldest): 1) Quaternary (~2.5-0 Ma) playa-lake/marine/lacustrine sediments, volcanics, salt formations and Dogua Mountain (Mtn)-derived alluvium deposited in the Danakil rift basin (Zariga, Dogua and Aden Formations [Fm]); 2) Tertiary shallow marine/lacustrine sedimentary rocks and volcanics from the Palaeogene and Neogene (~25-2.5 Ma), deposited in the Danakil rift basin during an early stage of its development (Afar Fm and Danakil Group [Gp]); and 3) Pre-Tertiary bedrock including clastic and carbonate sedimentary rocks from the Jurassic (~230-145 Ma; Adigrat Fm and Antalo Gp) and Late Proterozoic-Early Cambrian (~1000-540 Ma) basement rocks (phyllitic metasediments and metavolcanics; Tsaliet Gp). Of the divisions defined above, 1) and 2) are confined within the boundaries of the current rift system, whereas 3) is much more widespread and affected by older block faulting and folding, which frequently juxtaposes Jurassic and basement rocks along normal (and in rarer instances, older pre-rifting thrust/reverse) faults with large throws. This disruption of the pre-Tertiary stratigraphy is important hydrogeologically, in that groundwater from higher elevation recharge areas to the west flows between Jurassic and Precambrian units through interconnected fractures and faults, in turn discharging into and recharging the overlying Tertiary and Quaternary sediments within the rift basin to the east.

In the vicinity of the N/S-orientated Dogua Mtns in NE Ethiopia, 4 hydrostratigraphic units are recognised: 1) Basement Tsaliet Gp rocks that form a relatively impermeable, low-yielding, poor quality aquitard; 2) Adigrat Fm and Antalo Gp fractured sandstones and limestones, respectively representing more permeable fractured rock and/or karstic aquifer units with good quality borehole yields of ~3-5 l/s, but up to ~20-40 l/s in areas with thick overlying alluvium, e.g. the Lelegheddi River in the Ayshet Graben W of the Dogua Mtns; 3) Danakil Gp and Zariga Fm fine-grained sediments, which are unlikely to constitute a significant regional source of fresh groundwater (although local primary and/or fractured-rock aquifers are potentially present in conglomerates and sandstones of the Middle Danakil Subgroup, while local karstic aquifers may be present in the limestones of both the Danakil Gp and Zariga Fm); 4) Dogua Fm alluvial fans on the W side of the rift basin, which form a major, regional primary aquifer

(fan boreholes can have yields of 50 l/s, although groundwater is highly saline [up to 3x the salinity of seawater] and can reach temperatures of 50°C). Groundwater yields of hundreds of millions of m^3/a are potentially available from the saline Dogua Fm alluvial-fan aquifers for potash solution mining, whereas groundwater from the Antalo Gp karstic aquifers could provide a freshwater resource to settlements within the Lelegheddi River basin and the Danakil.

Reference:

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