Geomechanical modeling as a tool for groundwater exploration of fractured rock aquifers in the Namaqualand region, South Africa

SUMMARY

Groundwater-resource developments in hard-rock fractured aquifers are generally associated with conductive fractured zones characterised by high transmissivity. Identifying relatively highly productive borehole locations in these fractured-rock environments is an extremely difficult exercise as numerous dry wells are a demonstration of unsuccessful target selection.

A new procedure has been tested to evaluate the potential relationship between known groundwater abstraction locations in fractured-rock environments and geomechanically-modelled sites of high dilatancy. SMT is a computer-based method, relying on rock mechanic principles and stress-strain relationships, which seeks to transform strain data, in the form of a solid geology map, to stress data.

A modelling technique in which dilatancy (fracture permeability) in the crust is due to variations in mean stress allows for the wide variety of structural settings of fractured-rock localities, as these variations are a consequence of regional deviatoric stress acting on an inhomogeneous rock sequence, and a wide variety of potential sites of mean stress, dependent on variations in rock competency, and patterns of faults, fractures or shear zones. Thus a technique that measures variations in mean rock stress, such as SMT, has potential to generate viable dilatant sites, which could be exploration targets for fractured-rock aquifers.

In areas where the SMT method is applicable, a main advantage over previous lineament-analysis procedures is that once the tectonic history of a given area is determined, it is possible to predict which structural features, or combinations thereof, would likely be targeted for groundwater development. In this way, the siting of new boreholes can more effectively be facilitated, even in areas where no previous borehole information exists. The approach can be applied to other areas where a reasonable understanding of the most recent history of brittle tectonics exists. Through SMT and lineament analysis, therefore, the hydrogeologist can correlate the lineament directions with the various kinds of brittle structures known to be related to extension stresses.

The congruence of stress anomalies and known groundwater abstraction locations, as well as fracture density and fracture frequency in the study area demonstrates the usefulness of the technique as an additional data layer in groundwater exploration.