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For the degree of: Doctor of Philosophy
Department: Geosciences

Title: Structural Control of the Continental-Scale Nubian Sandstone Aquifer System Constrained by Hydrochemical, Stable Isotopes, and Noble Gas Data

Committee:
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10:30 a.m. to 12:30 p.m.
1192 Rood Hall

The Nubian Sandstone Aquifer System (NSAS) of northeastern Africa is one of the largest confined fossil-water aquifer systems in the world, with several nations relying on it (Egypt, Libya, Sudan and Chad). This groundwater is the biggest and in some cases the only future source of water to meet the development goals of each NSAS country. Groundwater extraction in the past 40 years has led to a continuous drop of water level and to the disappearance of most of the naturally flowing wells and springs. This study focuses on the connection between water quality, water management, and tectonics. Results of this study will help in the development and sustainable management of the continental-scale Nubian Sandstone Aquifer System.

Groundwater samples from the NSAS and potential recharge units form the basis of this study. Samples were analyzed for major and minor element composition, stable water isotopes, and noble gases isotopes. New data were collected from the Western Desert of Egypt from deep wells in the main Oases, from north: Bahariya, Farafra, Dahkla, Kharga, and Kurkur; these we combined with all published, including from Kufra basin of Libya. Geochemical results show variable temperatures (22 – 56°C) reflecting geothermal
activities; dissolved inorganic carbon ranges to more than 308 mg/L as bicarbonate; TDS and pH values are low, CO₂ is high, and high iron content impairs water quality. Sources for the high CO₂ include dissolution of carbonates and “external carbon”. External C is estimated as the difference between bicarbonate alkalinity (dissolved inorganic carbon [DIC]) and the C dissolved from carbonate. External C is further separated using carbon isotopes into biogenically derived carbon (organic C) and deep inputs (endogenic C). Water chemistry mixing models indicate that an average of 20% of the total DIC comes from dissolution of carbonate rocks, 44% from organic carbon, including microbial respiration as well as oxidation of sedimentary organic carbon, and 36% from deep (endogenic) sources. Helium isotope values (³He/⁴He) in gases dissolved in the NSAS groundwaters range from cratonic values of 0.03 Rₐ to values of up to 0.36 Rₐ (relative to air) in Dahkla Oasis and 1.5Rₐ for Libya. This suggests that deeply sourced fluids, including mantle-derived ³He, are leaking into the NSAS along the fault systems from below the aquifer.

Faults may also cause hydrologic partitions and connections between aquifer sub-basins and, consequently, indicate more complex flow models for the NSAS. Tectonic influences on the NSAS also have implications for variability of the water quality that may become more pronounced as the aquifer is increasingly utilized. Understanding heterogeneity of water quality and flow paths in sub-basins will become increasingly important as a management tool. A next generation of studies, integrating multiple hydrochemical tracers, can continue to test this hypothesis of a heterogeneous Nubian aquifer system with complex flow paths, sub-basins partitioned by faults, and fluid ascent and mixing along faults.