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Heterogeneity of hydrogeological conceptual models in crystalline basement aquifers under equatorial climate: case study of French Guiana

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Crystalline rocks aquifers are usually represented with a low porosity and hydraulic conductivity giving low well yields. Over the world, more than 880 millions people live on crystalline basement rocks. Thus, abilities to spot sufficient groundwater resource in these systems are crucial. Nevertheless, assessment of the sustainable reservoirs in crystalline basement aquifers is challenging. The well-admitted conceptual model presents a stratiform-weathered profile above a fractured zone showing a decreasing fracture density with depth. The interconnection between these two compartments defines the hydraulic parameters: the weathered profile is capacitive while the fractured zone is transmissive.

French Guiana is mostly composed of Paleoproterozoic rocks belonging to the Guiana Shield. It was formed during protracted periods of intense suprasubduction related magmatism, metamorphism and deformation, culminating with the Transamazonian orogeny, bracketed between 2.3 and 1.9 Ga. This peculiar geological history creates a large diversity of geological units from undeformed granitic units to ultramylonitized shears-zone related meta-volcano-sedimentary units and through brittle to ductile deformed units. Furthermore, over almost 200 Ma, the French Guiana recorded a deep weathering phase leading to heterogeneous and complex profiles up to 80-100 m deep. In such a context, hydrogeological exploration is thus puzzling, especially as French Guiana is covered by the Amazonian Forest, reducing direct observations.

We use a multi-disciplinary method from remote sensing to field observations through geophysical tomography to propose conceptual models of groundwater circulation helping us to localise precisely (meter scale) exploration borewells. After 15 years of hydrogeological surveys, the BRGM has studied plural units: (i) classical isotropic unit (Mahury Massif (MM)) and Granitic unit (Mana), (ii) ductile to brittle deformed units separated by strike-slip fault (Rosebel-Bonidoro unit (RBU) and Armina Unit (AU)), (iii) ultramilonitized unit (Paramaca Unit (PU)). A large heterogeneity of hydrogeological conceptual models for each context arise from our results. Notwithstanding this diversity and thanks to these conceptualizations, we were able to propose successfully useable sustainable resources, confirming the robustness of the method.

The MM and Mana are classical isotropic units displaying a deep weathered profile. The confined aquifer is located into the fractured layer with yield reaching 15 $m^3.h^{-1}$. Crosscutting dolerite dyke is attested to be an interesting hydrogeological target with yield near 20 $m^3.h^{-1}$. The highest yields in French Guiana for crystalline basement rocks (30 $m^3.h^{-1}$) are found in confined aquifer in PU context. This record could be due to the ultramylonitic deformation giving a high permeable unit. Three different places were studied for the AU (Sparouine, Roura, Beauséjour). As for the PU, aquifers are all confined. Yields are systematically low (around 2-5 $m^3.h^{-1}$). The RBU is an interesting and contrasting unit because it does not show developed weathered profile. It seems that an unconfined aquifer must probably recharge surroundings units (i.e. PU and AU).

This work highlights the high potential of ductile to ultramylonitic shear zones for groundwater resource. Taking together, these conceptual models highlight that, in French Guiana and probably in entire Guiana Shield, Transamazonian tectonometamorphic structures as well as early Jurassic extensive faults correspond to sustainable useable groundwater resources.