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Ground-Water Potential: A Predictive Model from Airborne Geophysical, Radiometric, and Remote Sensing Data, Ceará, Brazil

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Abstract. Preliminary results are presented that map locations permissive for ground-water resources in crystalline bedrock from airborne magnetic, electromagnetic, radiometric, and Landsat 7-ETM+ data. Predictive models were generated using the probability ratio method, a raster-based GIS technique. Results distinguish preferential values of magnetic, electromagnetic, radiometric data, and Fe, OH minerals in soil that characterize rocks where low- and high- yield wells are located, and hence to map other localities where similar conditions are expected to occur.

Key words: probability ratio, GIS, ground-water, crystalline, Ceará, Brazil, razões de probabilidades, geoprocessamento, água subterrânea, cristalino, Ceará, Brasil

1. Introduction and Study Area

The probability ratio method is a predictive modeling technique created for a geoenvironmental application (Lee et al., 2001) and has since evolved to include mineral resource applications by Silva (1999) and structural analysis by McDougal et al. (in press). In this study, we apply the technique to identify ground-water potential within crystalline bedrock.

The 144 km^2 study area is centered on the village of Juá within the southwest part of the Irauçuba Municipality, at Ceará State. The geology comprises Late-Proterozoic migmatites and biotite-gneisses intermixed with marbles, amphibolites, granites, and minor quartzites.

2. Data Sets

Water yields from 20 drilled wells with depths between 60 and 80 m described in Veríssimo and Feitosa (2002) and from wells sampled for this study, were grouped into 4 classes, based on yield ranges (**Table 1**). One-hundred-meter proximity zones were calculated around the wells and then transformed into a raster image with pixels of 25 m.

Table 1 - Yield classes for Juá area.

Yield (Q) Class and Range (m^3/h)	No. Water Wells within Class	Pixels within Class (25 m size)
Class 1 (Q < 0.3)	3	154
Class 2 (0.3 < Q < 1)	9	426
Class 3 (1 < Q < 2)	3	149
Class 4 (Q > 2)	5	232

Airborne geophysical data analyzed for this study include high-resolution magnetic and electromagnetic frequency domain/HEM by Lasa (2001), and regional radiometric and magnetic data (Lasa, 1978). The geophysical and radiometric data were used to determine if the well yield classes could be geophysically or mineralogically distinguished. The magnetic data were reduced to the magnetic north pole and high-pass filtered to emphasize shallow magnetic sources estimated to be located within 60 m of the topographic surface. The filtered magnetic and electromagnetic data were transformed to physical property maps of magnetization and electrical conductivity (Cordell and McCafferty, 1989). Flight-line data from the regional radiometric uranium (U), thorium (Th), and potassium (K) data were microleveled, filtered, and gridded.

Band ratios from Landsat 7-ETM+ data (b3/b1, b4/1, and b5/b7), were calculated to highlight Fe-oxide and hydroxyl minerals (clay) and vegetation cover. Each band ratio was divided into 3 classes of high, medium, and low values, and high-pass filtered to eliminate outliers, then combined into an 18-class raster image. Digitized interpreted lineaments from air photos were classed in azimuth range, buffered with 50 m side, and then converted to a raster image. All raster data layers have 25-m cell size, the size of the main geophysical data.

3. Methods

Assumptions are that the various data layers can reveal geologic discontinuities and different weathering characteristics essential for ground-water occurrence within the crystalline bedrock. Therefore, it was assumed that these geophysical, mineralogical, radiometrics and spectral rock/soil properties be predictive indicators of ground-water presence.

To quantify how characteristic (or not) the geophysical/radiometric/spectral data are of rocks with low- and high- yield wells, we applied a statistical approach developed by Lee and others (2001). The approach uses a ratio of probabilities to describe the statistical likelihood of a class of a particular evidential layer having a spatial association with a given prototype area. For this study, the evidential layers are the data layers described above, and the prototype areas are defined as the proximity zone of wells within the four yield classes (Table 1).

4. Predictive Models based on Probability Ratios

Preliminary model results show that the water well locations have the following characteristics:

a) Negative magnetization values are positively associated with the highest yield classes 3 and 4;
b) Strong positive correlations exist between yield class 4 and high conductivity HEM values, and, except for class 3, negative association with less-conductive units is common;
c) High K, and medium U and Th content are most likely to occur in association with high-yield wells, while soil and rocks containing low K, low U with high Th values are related to low-yield classes. High U and low Th grades were not found in any yield classes;
e) North-south-trending air photo lineaments are positively associated with the highest yield classes, while the E-W-trending lineaments correlate with lowest yields (classes 1 and 2);

f) All the yield classes show strong positive correlation with soils and rocks containing medium amounts of Fe-oxide and medium-high amounts of clay minerals. Yield class 4 showed the highest probability to be associated with these minerals;
g) High Fe-oxide, high clay mineral content, and little to no vegetation cover are least likely to characterize any of the water well locations.

5. Conclusions

Preliminary model results show that favorable regions for high-yield water wells are characterized by non-magnetic, electrically conductive bedrock transected by N-S-trending lineaments. The remote sensing and radiometric properties indicate that high-yield wells are characterized by sandy rather than clay-rich soils. Mineralogically, favorable regions for high-water yields are mapped in areas with high potassium, moderate uranium, moderate thorium, and moderate Fe-oxide and clay mineral concentrations.

The airborne geophysical, radiometric, and remote sensing data available for Northeastern Brazil may be useful to assess ground-water potential in similar fractured crystalline rock environments using the methodology described in this report.

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