Groundwater exploration by VLF techniques: a case study in granitic terrains of Northwestern Portugal

L. Macedo(1) & A. S. Lima(2)

(1) Departamento de Ciências da Terra, Universidade do Minho, 4710-057 Braga, Portugal, 351 253 604035, lfvmacedo@sapo.pt
(2) Departamento de Ciências da Terra, Universidade do Minho, 4710-057 Braga, Portugal, 351 253 604035, aslima@dct.uminho.pt

Geophysical groundwater prospecting techniques, generally speaking, base themselves on the detection of the abnormal physical fields associated with inhomogeneities that the geological evolution has “printed” on the Earth’s crust structure and geological composition.

The VLF (Very Low Frequency) technique, in its most recent portable version of equipment, can summarily be characterized as the detection of electromagnetic anomalies caused by induction from a primary magnetic field of worldwide distributed military use VLF transmitters on water bearing zones, such as fracture or fault zones of high electric conductivity acting as conductors, imbedded in high electric resistivity geological formations. These features, along with the portability and low cost effectiveness use of the VLF equipment, make it the ideal tool for groundwater prospecting associated with deeper paths along sub-surface water bearing bodies (fractures and fault zones) in hard rock geological environments.

A groundwater exploration program using the VLF technique was carried out in the Vieira do Minho area (Northwestern Portugal). Geological setting is dominated by biotite-rich coarse-grained porphyritic granite crossed by quartz veins and some basic rock dikes. Several sets of fractures break up the granite massif yielding a chaotic relief constituted by the individual rock blocks generated by rock fracturing.

The VLF data was collected with WADI, a two component magnetic receiver developed by ABEM Corporation that operates in the frequency range 15-30 kHz.

The measurements of the VLF campaign over the area were carried out with various profiles of varying length. Readings along those profiles stepwise 5 m intervals. Another important issue involved in the planning of the surveys was the necessity to maintain the orientation of the profile when taking the readings along its length. So, a system was constructed to help in this matter, consisting of a wire marked every 5 meters tightly stretched along the profiles.

The profile schematic applied on the area consisted of grid and isolated profiles. The first aimed at determining the spatial distribution, accordingly to the terrain possibilities, of the promising structures detected by the exploration goal of the seconds. Thus far, the VLF campaign over the study area has generated 21 profiles between grid and isolated forms. The data of these profiles that, summarily, is analyzed on the base of the relation between the horizontal primary magnetic field and a vertical secondary magnetic field originated by induction on a sub-surface conductor, was performed automatically with ABEM’s SECTOR program. The Karous Hjelt filter offers the possibility to generate current density pseudo-sections which, by showing the distribution of the apparent current density along the depth, provides a pictured image that can give an idea of the conductors geometry that originated the anomaly.

The data thus far gathered suggests that most of the anomalies detected are small and shallow. They also seem more to translate a series of high density fracture zones, poorly penetrating, rather than one isolated big fracture or fault zone, being difficult to extract a general dip orientation. Supporting this conclusion is a grid with 10 profiles oriented N240º that, when analyzed with filter, depths below 10 meters depict two more conspicuous lineaments with a general orientation of 190º-200º, thus requiring a reorientation of the profiles in order to explore an adequate perpendicular direction to those lineaments. The current density pseudo-sections for these profiles reveal a rather small depth reach of most conductors, although in some profiles some conductors reach as much as 30 to 40 meters deep. Also, a grid consisting of 3 parallel profiles orientated N-S shows two lineaments approximately perpendicular to that orientation. In one case, there is a profile with an orientation N52º that clearly depicts a shallower (20 meters deep approx.) conductor at 120-130 meters in length indicating a dip towards NE and a deeper (40 meters approx.) vertical conductor at 150-170 meters in length.

The interpretation of the data so far gathered in the VLF prospecting campaign enables to define some promising areas of hydrogeological potential, on the basis of preferential lineaments identified and also taking in to consideration the general depth of the conductors they contain.

As an end remark, a reference should be made to the difficulty of selecting an adequate transmitter whenever the profiles require their orientation to be around NW. This leads to the conclusion that the prospecting potential of this equipment could greatly be enhanced with a portable VLF primary magnetic field generator with the inherent disadvantages that such equipment would carry.
Luís Macedo is a graduate in Biology and Geology from University of Minho – Portugal and is currently developing an investigation on groundwater prospecting and sustainability in hard rocks using geophysical techniques, namely the Very Low Frequency method, for his MSc degree.

Mail address: Departamento de Ciências da Terra, Universidade do Minho, 4710-057 Braga, Portugal
E-mail: lfvmacedo@sapo.pt
Phone: +351 253 604035
Fax: +351 253 678206

Alberto S. Lima is a graduate in Biology and Geology Teaching from University of Minho, Braga 1986, Portugal, where he returned later to take his Msc (1994) and PhD (2001) in Hydrogeology of Hard Rocks. In addition to the research developed at University of Minho, especially devoted to thermal and mineral groundwater, he’s teaching also many courses in graduate and postgraduate programs.

Mail address: Departamento de Ciências da Terra, Universidade do Minho, 4710-057 Braga, Portugal
E-mail: aslima@dct.uminho.pt
Phone: +351 253 604035
Fax: +351 253 678206

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