USE OF GPR IN PEGMATITE MINING: EXAMPLE OF A SHEETLIKE BODY FROM NORTHERN MINAS GERAIS, BRAZIL

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Abstract: Located in the region of Teófilo Otoni, Brazil, the Santa Rosa Pegmatite Field is known for its gem-quality tourmalines. It formed from late-stage fluids during crystallization of the Santa Rosa Granite in the late-tectonic phase of the Neoproterozoic Araçuaí Orogen. The pegmatite structure is zoned, with wall, mural and intermediate zones and a small, discontinuous quartz core and gem mineral pockets distributed along determined zones (lines) between the intermediate zone and the core. The investigations with GPR in surface and subsurface profiles, at the galleries, allows the identification of the limits of the pegmatite and the zones, and also the orientation of pocket bearing areas (lines), the distribution of these mineralized corps (substitution pockets) and the estimation of the orientation of pocket evolution (lines). This is possible due to changes and differences in the density of ~~the~~ different compartments of the pegmatite, the wall rock and the pockets, permitting to register their contacts. The GPR profiles interpretation allows the detection at least two anomalies (hyperbolae shape) with gems in its interior.

Key words: Pegmatite, ground penetrating radar, prospecting

1. Introduction

Gemstone mining is a traditional economic practice in Northeastern Minas Gerais State, Brazil. This region is located in the Eastern Brazilian Pegmatite Province (EBPP) (Paiva, 1946; Putzer, 1976), and hosts several pegmatite districts, including the Santa Rosa Pegmatite Field (SRPF) (Netto et al., 1997), localized at 40km SW of Teófilo Otoni city.

Despite the importance of gemstones for the local economy, exploitation takes place in rudimentary digs and efforts to optimize their prospecting are scarce. In an attempt to partially fill those voids, pegmatite-hosted minerals were sampled in an underground work and subjected to basic chemical analyses to compare mineralized and non-mineralized points and to help understanding the pegmatite crystallization process and its possible implications for gem tourmaline formation, as well as interpreting the tourmaline setting by the use of GPR radargrams to positioning the pockets relative to the pegmatite/schist contact.

The Ground Penetrating Radar, GPR, is an electromagnetic geophysical research method~~,~~ applied to subsurface surveys, based on the interaction of radio waves, between 10 MHz and 1.3 GHz frequency, with underground structures. The method has been applied in various fields, especially in forensic, geoscientific and archaeological investigations (Busby et al., 2004; Daniels, 2004; Everett, 2013).

In Earth Sciences, several areas make use of GPR in their research, with satisfactory results, as in stratigraphy (Hager and Carnevale, 2006), geotechnics (Aranha et al., 2006; Benson, 1995; Hara and Sakayama, 1984; Santos, 2014), pedology (Chaplot et al., 2004; Huggenberger et al., 1994), geomorphology (Aranha, 2002; Augustin and Aranha, 2006), environmental geology (Parizzi et al., 2011) and mining (Francke, 2012; Rafezi et al., 2015).

The GPR operates in a similar way to seismic reflection method. However, it employs electromagnetic waves instead of acoustic ones, and has a depth of investigation centimeters to decameters. A source emits the electromagnetic wave, which penetrates the underground and interacts with its structures, suffering changes in reflection patterns due to contrasts of electric permittivity, which is caused by structural anomalies or geological contacts. A receiver captures the reflected wave. A processing unit amplifies and adjusts the acquired signal and relays it to a computer, which displays and stores the information (Busby et al., 2004; Davis and Annan, 1989; Everett, 2013; Milson, 2003; Santos, 2014).

Academic papers about the application of GPR in pegmatites are still rare. In general, the surveys conducted are private property and the access to their results~~,~~ restricted. In fact, only two authors have produced publications regarding in the State of California (USA): Frederick A. Cook, PhD, and Jeffrey E. Patterson, PhD, originally producing independent works and later in joint research. Patterson (1996) conducted the first survey focused on detection of pockets in pegmatites using GPR at the Little 3 Mine. Later, Cook (1997, 2002) included the GPR in a report of geophysical methods applied to gem exploration. Together, Patterson and Cook (1999, 2000, 2002, 2004) disseminate the results of their investigations in a Himalaya mine, these being the most important publications up to date. Their research was driven by observation of patterns like form, color and organization of the minerals. The gems were found usually in oblong, flattened, and filled with clay or zeolite cavities with their edges parallel to the contact between the pegmatite and the host rock.

2. Regional setting

The SRPF is located between the cities of Franciscópolis and Itambacuri, in the crystalline core of the Neoproterozoic Araçuaí Orogen (Fig. 1). Its formation is associated to the emplacement of Santa Rosa Granite, a late-collisional suite (Bayer et al., 1985, 1987; Oliveira, 2016; Paes, 1997).

The granite intruded biotite schists and gneisses of the São Tomé and Tumiritinga Formations, metasedimentary marine units deposited in arc-related basins. This was not the first plutonic event in the area, as it followed the also late-tectonic intrusion of the São Vitor Tonalite (Oliveira, 2016; Vieira, 2007) B-assimilation occurred during emplacement, causing schist tourmalinization (Oliveira, 2016).

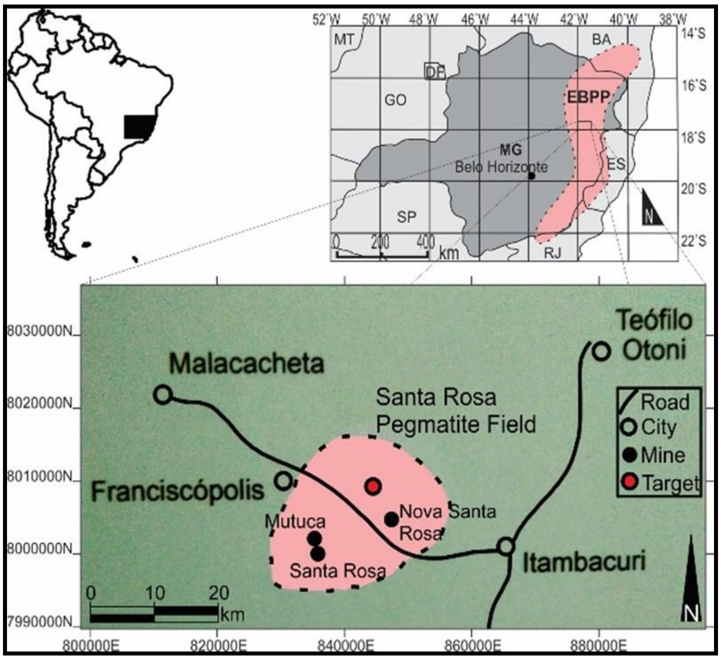


Fig. 1: Map of the Santa Rosa Pegmatite Field localization.

3. Geology of the studied area

Santa Rosa Pegmatite

The studied pegmatite is an 8m thick dyke, which intruded biotite schists of the São Tomé Formation concordantly to its foliation, zone with thick (blocky) feldspar crystals; and d) small, discontinuous quartz core. Tourmaline crystals or agglomerates that grow from the margin of a zone to its center are a frequent feature. Subordinate pegmatite intrusions and apophyses are found in the main dyke's vicinities.

Gem-tourmalines in the pegmatite are blue or green, and may occur in pockets (miaroles), cavities formed by late-stage substitution processes controlled by fluxing components exsolution from the melt (London, 1986 a, b, 1987; Simmons et al., 2012). These geodes may also bear black, non-gemological tourmaline or contain no tourmaline whatsoever, on which case filling is composed by clay, mud and water. Pocket frames in the studied dig usually show star-shaped muscovite crystals.

4. Material and methods

In nine profiles from the walls of the tunnels in the pegmatite, were taken GPR data with structures that could match the possible cavities (popularly known as potholes or pockets).

The antennas, with central frequency of 100 and 200 MHz, were arranged parallel (common offset), connected via the processing unit to a computer, which retransmitted the signal (Fig. 2). The registration was done using the program Malå Groundvision. The capture, horizontal step, was executed every 5cm travelled and the Computer processing of the collected data consisted of: Declipping, Dewow, Set time zero, Window time range, Removal background, Gaussian Filter, Elevation static (wall static), Time to depth conversion.

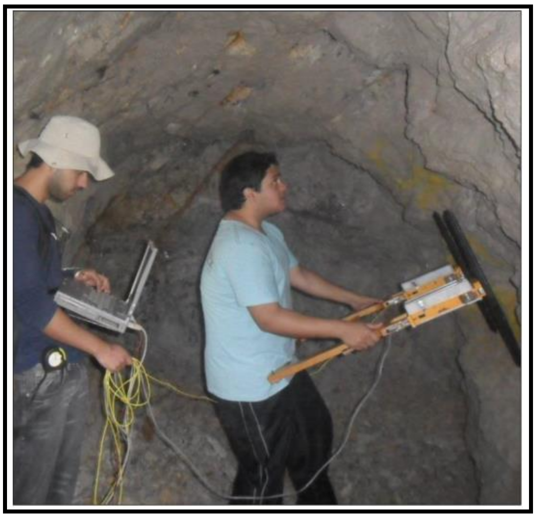


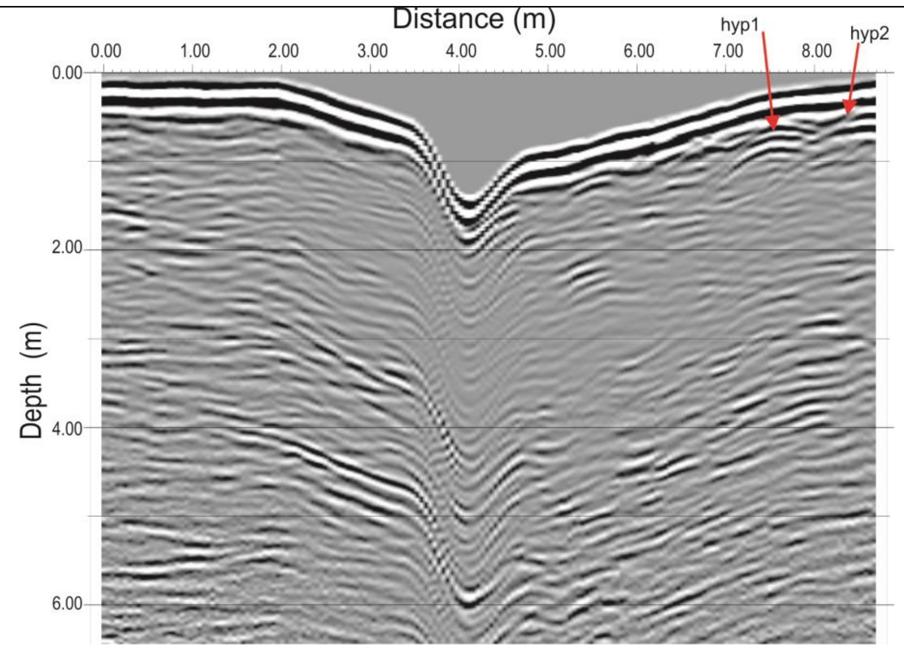
Fig. 2: Photo of the acquisition of GPR profile on the wall of the pegmatite rock.

5. Results

In the radargrams obtained by GPR profiles, it was possible to observe variation patterns in the reflection of electromagnetic waves patterns, corresponding to puncture-like and planar structural anomalies within the pegmatite, or to the contact between the pegmatite and the host rock (Micaschists s.l.).

Using the detected hyperbolae, the velocity of electromagnetic waves propagation in the pegmatite was set to 110 m/μs. Associating the performed profiles to topographic survey of the walls, it was possible to spatially locate the anomalies.

The radargrams obtained on the wall of the tunnel 1 show two distinct hyperbolae at well-defined distances of 7.5 and 8.4m. These two hyperbolae are clearly visible in both radargrams, one obtained with antennas of 100 MHz (Fig. 3a), and another obtained with antennas of 200 MHz (Fig. 3b). Also, is to note in the second radargram a little hyperbolae (hyp3), less pronounced, on the left side of the hyperbolae - hyp1. These anomalies were investigated and underground works were made, resulting in the finding of pockets filled with gems.



a)

Fig. 3. (see explanation on the next page)

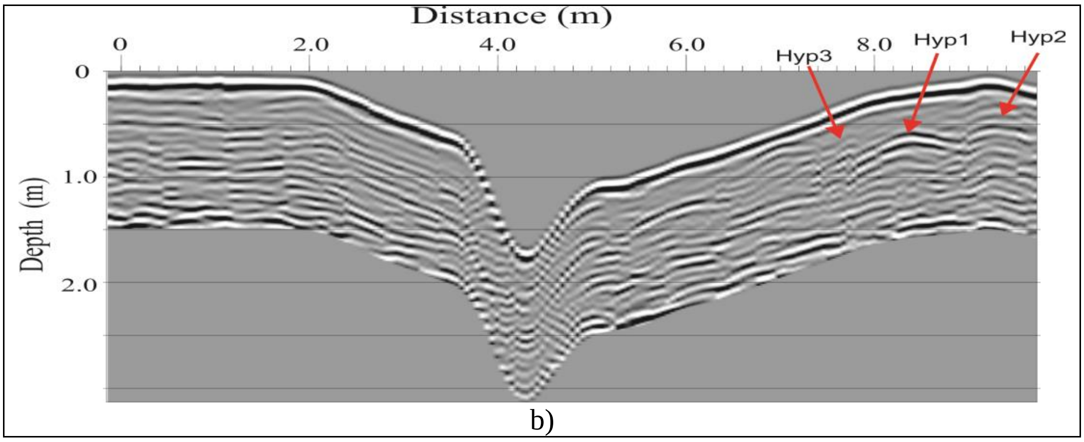


Fig. 3: a) Radargrams obtained with the 100 MHz antennas, showing two hyperbolae - pockets indicated by the red arrows; b) radargrams obtained with the 200 MHz antennas on the same wall showing three hyperbolae.

Other profiles were performed on different walls and it was possible to observe in the radargrams obtained with antennas of 100 MHz (Fig. 4) the presence of reflections, probably associated with structures in pegmatite. In general, these structures may be related to fractures filled with clay.

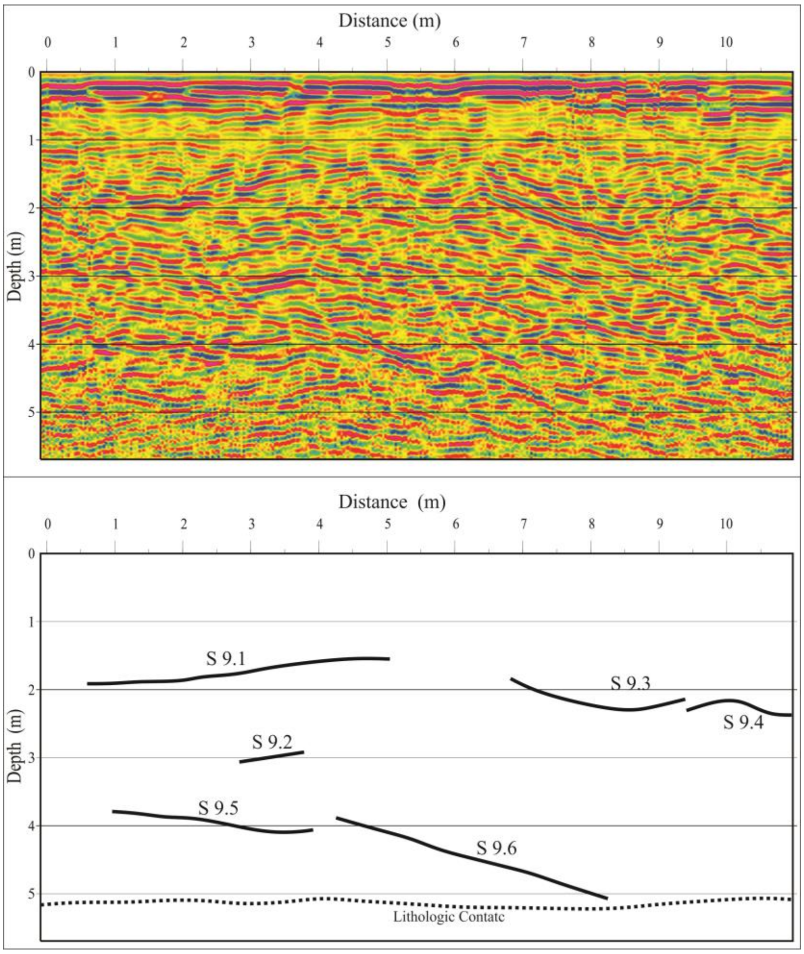


Fig. 4: The radargram at the top obtained in wall 9, is showing such related reflections correlated with the internal structure of the pegmatite. The lower part of the figure shows the interpretation of the upper radargram.

Another result well marked by GPR investigation was the identification of the contact between the pegmatite and the host rock formed by micaschists. In Fig. 5 one may observe various types of reflections, hyperbolae~~,~~ indicating pockets~~,~~ and linear reflections indicating the contact and clay-filled fractures.

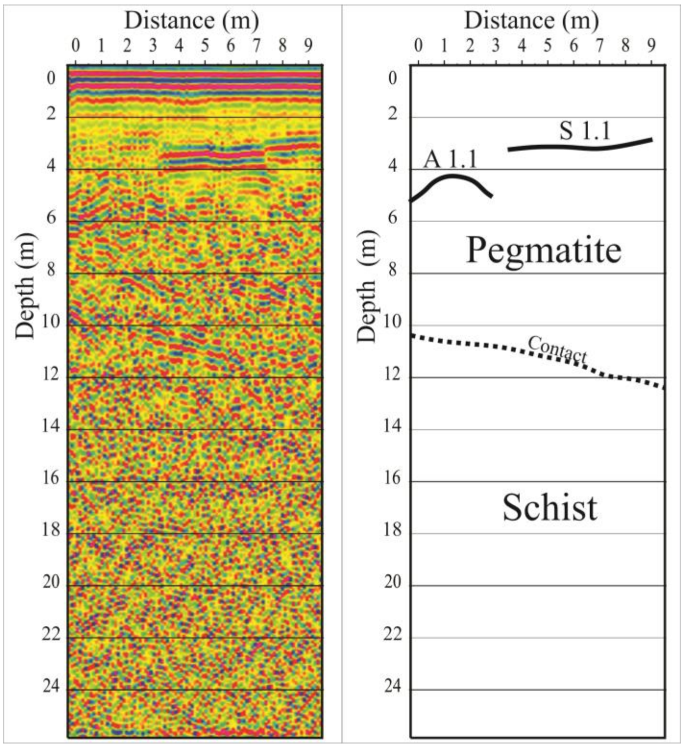


Fig. 5: Typical radargram obtained in the research and its interpretation.

6. Conclusions

In the same way as in various fields of Geosciences, the GPR method proved to be an effective tool in the investigation of the pegmatites, corroborating the proposals of Cook (1997, 2002) and Patterson and Cook (1999, 2000, 2002, 2004). The investigation profiles carried out have not only detected the pegmatite-host rock limits, but also structural anomalies inside the pegmatite, especially represented by ~~of~~ hyperbolic patterns, indicating pockets filled with gems.

The planar anomalies found in the pegmatite are predominantly parallel to the direction of intrusive body. Their meaning is debatable. These surfaces can be related to compositional or structural variations within the pegmatite, marking, for example, the boundary between the wall and the border zone. Another possibility is that these anomalies correspond to a set of fractures parallel to the foliation of the schist of São Thomé Formation. These diaclases, besides the schistosity of the host rock, can be considered in this way as a facilitator for the emplacement of the pegmatite veins and dykes.

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