

POTENTIAL AREAS LOCALIZATION FOR GROUNDWATER EXPLORATION AND RECHARGE IN  
PARAIBA DO SUL VALLEY USING TM-LANDSAT - SÃO PAULO STATE-BRAZIL

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**ABSTRACT:**

Viewing to the social economic importance of the Paraíba do Sul Valley, São Paulo State - Brazil, a research work to identify the potential area groundwater recharge and exploration to orientate the regional development and planning, was carried out. This work was developed from analysis of the structures and tectonic datas of Landsat-TM image on crystalline terrain and was a part of a environmental zoning project.

**KEY WORDS:** Remote Sensing - Groundwater Recharge Structural.

**1. INTRODUCTION**

The water supply has been a trouble in the region where there is a great urban, industrial and agricultural development. The wrong use of the areas of the fountainhead with the contamination of water sources by urban and industrial sewerage system and agro-toxin turn this water inappropriate to human consum.

One way of helping the control and the reduction of the fountainhead polution, is to take a national using program to explore the groundwater, using a structural geological analysis, viewing to detect the best zones for recharge and the most favorable areas for groundwater exploration.

We used remote sensing products (TM-Lanbsat) at 1:250.000 scale, and previous geologic works in a regional level.

The results obtained were: map from structural lineaments and infered curves of the groundwater preferencial flux and map from the most favorable zones for recharge and groundwater exploration.

Some considerations have to be made about these datas, because they don't give a detailed tectonic and structural understanding. Then the maps have been used according to their interpretative charater wich folows:

a) The lineaments that represent zones of crystal weakness were normally policiclic.

b) The probable flow line of the subterraneous water obtained from assimetry and organization analisys of

the drainage pattern, shows one regional qualitative character. It doesn't mean that the percolation process does not occur in different directions in disagreement with the indicated strikes when observed in detail.

c) Places indicated as recharge sites ware more favorable but not the only ones. Other places can be found after detailed studies.

d) Places indicated as the best to be explored in the map are also not the only ones. They only show the possibilities of groundwater occurence. They do not exclude the possibility of occurence of other fountain heads in the area

We can conclude that maps of recharge and potential areas for groundwater occurence were only indicative. To indicate places to drill wells, it's necessary to make detailed mapping at these potential areas.

**2. METHODOLOGY**

A photointerpretation was made using remote sensing products and analysis procedures developed by Mattos and Veneziani 1985, and Sampaio 1986.

Several changes in this procedures system were made and the main sequence used during the work development was as follows:

a) A drainage pattern chart was made at the scale of 1:100.000 and after, it was

INTEREST MAIN STRUCTURES	OPEN ELEMENT	MXED ELEMENTS	CLOSED ELEMENTS
Fracture trend	1 Consugated system		1 Consugate system
	2 Systems		2 Systems
	3 Sets		3 Sets
IV Faults	1 Normal		1 Strike slip
			2 Inverse
			3 Thrust
III Faults-Trends	1 Open x Open	1 - Open-Closed	1 Closed x Closed
		2 - Closed-Open	
Faults-Faults	2 Open x Open	3 - Open-Closed	2 Closed x Closed
		4 - Closed-Open	
Trend x Trend	3 Open Open	5 - Open-Closed	3 Closed x Closed
		6 - Closed Open	
Folet-descontimily	4 Open x Descontinuity		4 Closed x Descontinuity
Trend-descontimily	5 Open - Descontinuity		5 Closed x Descontinuity
II Flow water tendency	C Agreement	D - Disagreement	
I Higt1 permability	A Pobosity	B - Density of Open Structural Element	

## Bibliografy

Mattos and Veneziani 1985

TABLE 1

reduced to a scale of 1:250.000.

b) The analysis of the joint structure zones obtained from drainage pattern, led to reconaissance of the great lineaments which were compared using Landsat-TM image.

c) Analysis and reconaissance of relief groups and drainage elements, that show the same behavior of the symmetry, asymmetry and directional trends.

d) Major linear elements were obtained from relief and drainage pattern which could be lineaments or faults.

e) Construction of the joint zones and fracture trends map based on observation of anomalies related to the change of direction of the structural trends.

f) Construction of the map of the infrared lines of the groundwater flow based in asymmetry data and major structural lines.

g) Integration of the results using the table one, and identification of the most important potential area for recharge and for groundwater exploration.

### 3. RESULTS

The study area was represented by crystalline rocks of the Paraíba do Sul Group and a small part of sedimentary rocks of Taubate Basin and (baixada litorânea low land of coast places).

We know that the permeability transmissibility and storage in crystalline rocks are data that depend essentially on the fracturing intensity and intercommunication and fracture on the formation and dissolution of calcic rocks and so on this groundwater accumulation in crystalline rocks is dependant of the existence of fountainhead nets.

These nets are different from the fountainhead and connected through systems of open fractures (faults or joints). The more intensely corrected, the system, the bigger, the probability of one higher water production in a drilled well.

In the study region it was recognized shear and strain processes in its rock complexes.

The analysis of these kinds of structures shows the following results:

a) Joint zones and fracturing trends are structures that represent the shear levels and shear-strain levels.

They appear controlling the stream and form one directional preferential trend. Its metric and centimetric spacement out lithologic units which have different ages and different origins. They have a very high dip and are related to very deep faults.

There are six strikes which are associated to the sets of the joint zones: N50-60E; N20-30W; N30W-EW; N20-30E; NS-N10E and N45W. Other strikes are not very important.

b) The structural lineaments: were associated to polycyclic structures in which strain, shear-strain and shear structures are recognized. They may also be associated to several tectonic and structural episodes, and to several kinds of movement.

The more important tectonic lines as the Cubatão fault, Taxaquara fault and São Paulo shear zone, have their main movements with a dextral character and a N50-60E orientation.

A tectonic evolution based in Riedel model to lines around the end of Proterozoic and the beginning of the Paleozoic (Figure 1) was accepted according to Sadowski 1974, 1983; Hasui et al. 1984.

Five preferential directions were recognized using this model. They present the following orientation:

- N50-60E orientation dextral strike slip faults, are the most important, and are parallel to the main shear;
- N20-30W antithetic faults;
- N80W-EW synthetic faults, related to R1 and R conjugate shear couple;
- N20-3-E dextral slip faults related to P fractures;
- N45W distensive fractures related to Riedel fractures. Another direction was recognized (NS-N10E) but with no clear association with the model. Figure 2 and 3.

Although the analogy between the data collected and the Riedel Model didn't permit a final conclusion about the tectonic evolution, the model used (due to the polycyclic character of this area) help in its understanding. The great complexity of the area requires a more detailed field work to verify the model validity.

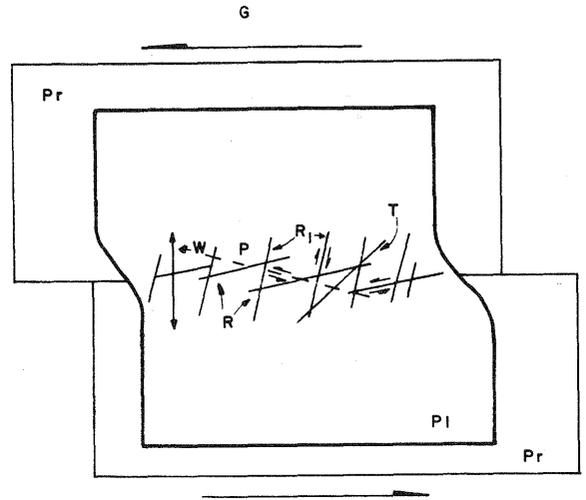
c) Lines of foliations - were recognized from associated linear drainage features of first order and from relief elements parallel to the main asymmetric axis.

There are cataclastic foliations and metamorphic foliation related to the last folding cycle that affected this region. Their direction was about N50E; there are also clivage fracturing, associated to the main faults. Foliations are shear and shear-strain structures, that help on the interpretation of the evolutive model, on the movement recognition and the groundwater movement understanding. They have a vertical attitude and may be a

favorable trend to water percolation.

d) The obtained data were integrated during the interpretation process and associated to Table 1. Then it was possible to find the best areas to groundwater exploration. The code used for Table 1 was the following: IAB Permeabilit I

(A) indicates the rocks porosity of Taubate Basin (B) fracturing of crystalline rocks; IIC concordant flux tendency; III AI2 - crossing of trend fracture will faults, both opened (1) and crossing of faults with fault, both opened (2); B 1234 - mixed elements crossing each other, opened-closed and closed-opened, with fracture trends crossing faults or faults crossing fracture trends (1, 2, 3, 4); IV A1C1 - normal faults (A1) and strike slip faults (C1); V A2C2 - fracture trend, opened system (A2) and closed (C2). It, means that in the indicated area the permeability of the substrate is function of the porosity of the inconsolidate materials of the fracturing density of that crystalline rocks. In consequence we can deduce that this area is located on crystalline and sedimentary rocks; the sets of the mapped joint zone have a compressive and distensive character according to Figure 3, the lineaments and faulting should be represented by shears and sheras-strain systems.



- G - General Direction Moviment
- W - Size of the shear zone
- Rand R' - Conjugale shear couple
- Pr - Table
- PL - Plate of the Slaty
- P - Sintetic fractures
- T - Tension

Fig. 1 - Modelo de Riedel.

Bibliography Riedel (1929), p. 25

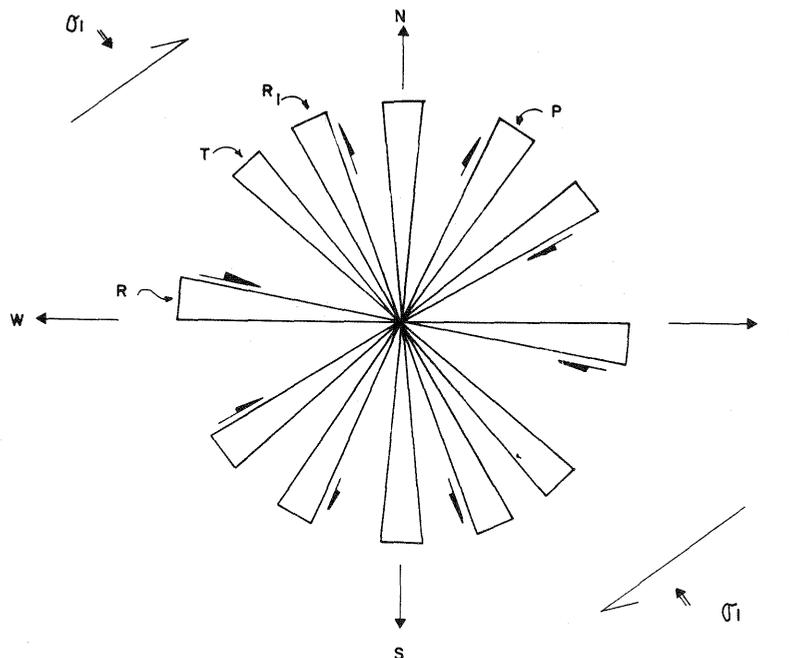


Figure 2 - Esquematic view of the spatial distribution in the study area.  $\sigma_1$  is the main stress direction according the adapted model.

e) Best areas to groundwater recharge and exploration. Two kinds of recharge areas where found. The closed areas where the flux occurs in every direction from the axis of the delimited region and the opened recharge areas, where the water flux occurs with a divergent movement from the longitudinal axis of the delimited area.

To classify the potential areas using the table there is a decrescent priority when the alfa numeric index of the Table 1 increases from down to up and from left to right.

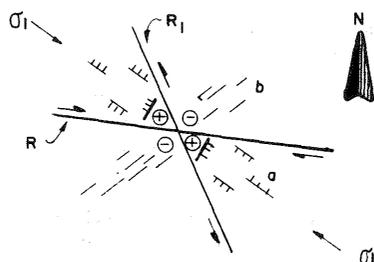


Figure 3 - Esquematic view of conjugate couple R-R1 of the tension systems (a) and axis direction (b)

#### 4. RECOMMENDATION

To localise good points to drill artesian wells a detailed study of the area is necessary using:

a) Photointerpretation of aerial photographs at the scale of (1:50.000 to 1:10.000) to map the fracture systems and to delimit the lithologic units.

b) Comparision of this framework with a regional model.

c) Field work viewing to identify the kinds of structure groups: series and systems, the space between these groups, the opening and the material with wich the fractures are filled, and to observe the kinds of movement thgat occur.

d) Use of the Table 1 on the map results and identification of the places where to drill or to make artesion wells.

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