Transfer of Technology in Remote Sensing Techniques for Groundwater Studies in Northeastern Brazil

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FINAL REPORT

INFOTIERRA

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INTRODUCTION

INFOTIERRA was mandated by the Geological Survey of Canada to provide remote sensing training to two Brazilian professionals from the Federal University of Rio Grande Do Norte. The training took place during 8 weeks between March 12th and May 4th 2001. Mrs. Ana Catarina Coriolano participated in the full 8 weeks of training while Prof. Dr. Venerando Amaro was present during the first 4 weeks, one week more than initially planned.

Thanks to the continuous effort and sustained interest which the Brazilian professionals showed during the training program, we are proud to report that the two candidates are now advanced users of remote sensing data (RADARSAT and Landsat TM) using PCI and IDRISI software. Furthermore, they are now very proficient in the management of spatial data using PCI, IDRISI and ArcView in applications adapted to groundwater exploration. This report describes briefly the various phases of the training that was provided during the specified period as well as some of the results to date.

TRAINING: PHASE I

The first Phase of the training concerned the structure of image data and the potential they offer in geological and hydrogeological applications. To this end Dr. Gwyn, specialist in radar remote sensing, presented several days of theory and case studies using radar data sets from various regions. Among others he presented the results of his studies in Shield areas in Canada and West Africa. In parallel with this, Dr. Péloquin, specialist in remote sensing applications and spatial analysis, directed the practical use of the remote sensing data provided within the overall Project. Specifically he provided training in the use of PCI and OrthoEngine. Along with this training, Mrs. Coriolano and Prof. Dr. Amaro participated in various seminars at the *Centre d'applications et de recherches en télédétection* (CARTEL) at the *Université de Sherbrooke*. Specifically, a special presentation was organized by Mr. Lacina Coulibaly (Ph.D. student) on the methods to extract lineaments from Landsat of the Abitibi region, northern Québec. They participated in a seminar by Mr. Samuel Foucher on the results of his Ph.D. research to study wavelet methods for filtering RADARSAT images. They also participated in the Ph.D. Thesis defence of Mrs. Charlotte Gaillard concerning the use of radar data for estimating soil erosion in agricultural areas.

TRAINING: PHASE II

The second Phase of training focused on the methods to extract information content from RADARSAT images. Firstly we concentrated on the creation of a DEM using two of the three RADARSAT images available in the *San Antonio* study area. During this activity, which is typically time consuming, all the individual activities went very well and an excellent DEM was generated. The resultant model had contour interval of 20 m and an average vertical error of 7 m based on the geodesic elevation control points. The DEM is both valuable and very useful

because the only other source of topographic data (1: 100 000) only had a contour interval of 40 m.

TRAINING: PHASE III

The third Phase had the objective of extracting the maximum information from the images concerning groundwater. For this we used directional filters (SOBEL among others) so as to enhance the fracture pattern characteristic of the Precambrian, Tertiary and Quaternary bedrock. To do this, a range of theoretical and practical alternatives was presented. They were applied to both the Ascending and Descending RADARSAT images because each contained different information from their different look directions. These filters were also applied with the Landsat image and the DEM.

In the second set of activities, we applied the automated lineament module (ALM) available in the PCI software. ALM was used with each of the filtered images in order to create a vector file of the distribution of the lineaments. Finally, in reference to the recent work by Robert St-Jean (CCRS) published in *Canadian Journal of Remote Sensing*, we fused the set of RADARSAT based data (4 orientations) using principal components. This resulted in the creation of a synthetic map that included all of the enhanced lineaments; all the direction together. Based on this composite image we used ALM to extract all the lineaments at once to produce the final lineament map.

In order to evaluate the quality of the results, we compared them with the results obtained by Mrs. Coriolano using visual interpretation methods from air photographs. Because the scale of the two data sets was different we could not do a direct comparison. Therefore we used ArcView

to calculate rose diagrams and used these to compare the results of the two methods. As a consequence, Mrs. Coriolano has also received specific training on how to transfer PCI formatted data into ArcView to obtain the final results. Comparison of the two rose diagram sets shows clearly that the automatically extracted lineament network has the same directional characteristics as those based on visual interpretation of the airphotographs at another scale.

We also demonstrated how to calculate lineament density, again using ArcView. Mrs. Coriolano had already done this visually. Comparison of the two mapped results shows that they are very similar. However the automatic method has the major advantage of being more objective.

TRAINING: PHASE IV

Although the available Landsat image of the study area included 20 % cloud cover, we used a supervised classification to extract the Land Use map. The objective of this Phase of the training was to examine traditional and Bayesian statistical classifications. The first activities established the training areas after using the optimum visual bands combination of the sites, which we then applied to the Landsat bands. In the next steps, the automatic classification was applied over a multilayer combination (RADARSAT, Landsat and DEM).

Based on the fieldwork by Mrs. Coriolano the classification results are very accurate. However, because we did not have a map of the whole area, we could not do a quantitative comparison (confusion matrix) of the automated classification.

As a demonstration we also presented different techniques of image fusion in order to obtain improved visual results. We also demonstrated how to remove the clouds and replace them with radar data.

In resume, in this Phase we introduced and applied the techniques using both PCI and IDRISI in order to demonstrate the advantages and disadvantages of each module.

CONCLUSIONS AND RECOMMENDATIONS

During the 8 weeks of training we succeeded in covering the complete program as planned and more. The strong background and professionalism of the Brazilian scientists allowed the team to go beyond the initial work plan. In fact we were able to discuss and demonstrate many of the modules of IDRISI and ArcView as well as PCI. This provided a much more thorough appreciation of the complementary modules in each. It also allowed us to go beyond the limitations which all software packages have and as a result the database that was produced reflects this increased flexibility.

The results obtained from the analysis of the two RADARSAT images to produce the DEM revealed an exceptional image of the topography. It is much better than would be available from any of the maps presently available in Brazil. For this reason, we consider it essential that the OrthoEngine 7.0 software be made available for this project in groundwater exploration.

Visual and digital analysis of the RADARSAT images proved excellent geological and structural information in comparison to the Landsat image or to the airphotographs, in which these features were only identified with difficulty. We believe that the RADARSAT data will play a significant

role in the future Phases of the Northeast Brazil Project. Quite apart from the information content in the RADARSAT images, the nearly constant cloud cover in the region makes the use of optical data nearly impossible despite the high information content concerning land use. The persistence of cloud cover was corroborated with EOSAT database.

Finally, we conclude that the Brazilian scientists have an advanced operational knowledge in the use of modern management and analysis of spatial and satellite data as used in this Project. At various stages we tested their skills by presenting hypothetical situations based on the data from the study and asked them to proceed with the appropriate analyses. Each time they were able to translate the specific geological problem into an appropriate analytical methodology using the available software. This confirmed for us that at progressive stages they really mastered the image analysis and spatial analysis techniques.