Session 3580

Cooperative Partnership Between Industry and Academia for Undergraduate Research Training: The North State Gold Mine Project[1]

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Abstract

Pyramid Environmental & Engineering, P.C. entered into a research partnership with North Carolina A&T State University to develop undergraduate research programs in geophysical and environmental sciences under the University's Talent-21 Program, funded by the NSF's HBCU-UP. One goal of this partnership was to develop research projects for undergraduate students that would be supervised by professional scientists and engineers. In the summer of 2001 we started the first such research project: a geophysical survey of an abandoned gold mine site, the North State Gold Mine, which was beginning residential development. There was concern that voids associated with former mine workings might pose significant geotechnical, environmental, and safety hazards as the properties were developed. Under the supervision of Pyramid's professional geophysicist, a group of three students conducted a 2-D Resistivity Survey of the property. First the students were introduced to geophysical surveying theory via a series of informal seminars/workshops. The students then collected over 900 meters of DC resistivity data along 13 profiles on the site. The students downloaded, processed, and interpreted the data. They located several potential voids in the subsurface that were later further investigated by geotechnical drilling. The students produced a joint written report on the project. They also presented a poster presentation of their work at the HBCU-UP National Research Conference in Albany, GA in February 2002. This project was a "win-win" for all involved: the industry consultant, the property owner/developer, the community, the university, and most of all, the students. We have since returned to the gold mine site to continue the research using different geophysical techniques and we look forward to more cooperative student research projects in the future.

[1] This work was supported in part by the National Science Foundation under the Grant HRD-9909058.

Introduction

Academia has long sought to involve industry in the educational process. This is especially appropriate in the scientific, technical, and engineering disciplines where students need more than classroom learning to prepare them to enter the industry workforce. Industry has a vested interest in the educational process to insure a good influx of young scientists, engineers, and technicians who have the skills and experience to contribute productively to their employer's bottom line. It is also important to the future of scientific, technical, and engineering fields that a well-rounded and diversified workforce includes currently underrepresented segments of the population. Unfortunately, the benefits to industry of investments in academia are often perceived as long term and relatively unquantifiable with no immediate short-term benefits. The North State Gold Mine Project represented a unique partnership between industry and academia that had immediate and substantive benefits not only for the students and the university, but for the industrial partner, the client, and the community as well.

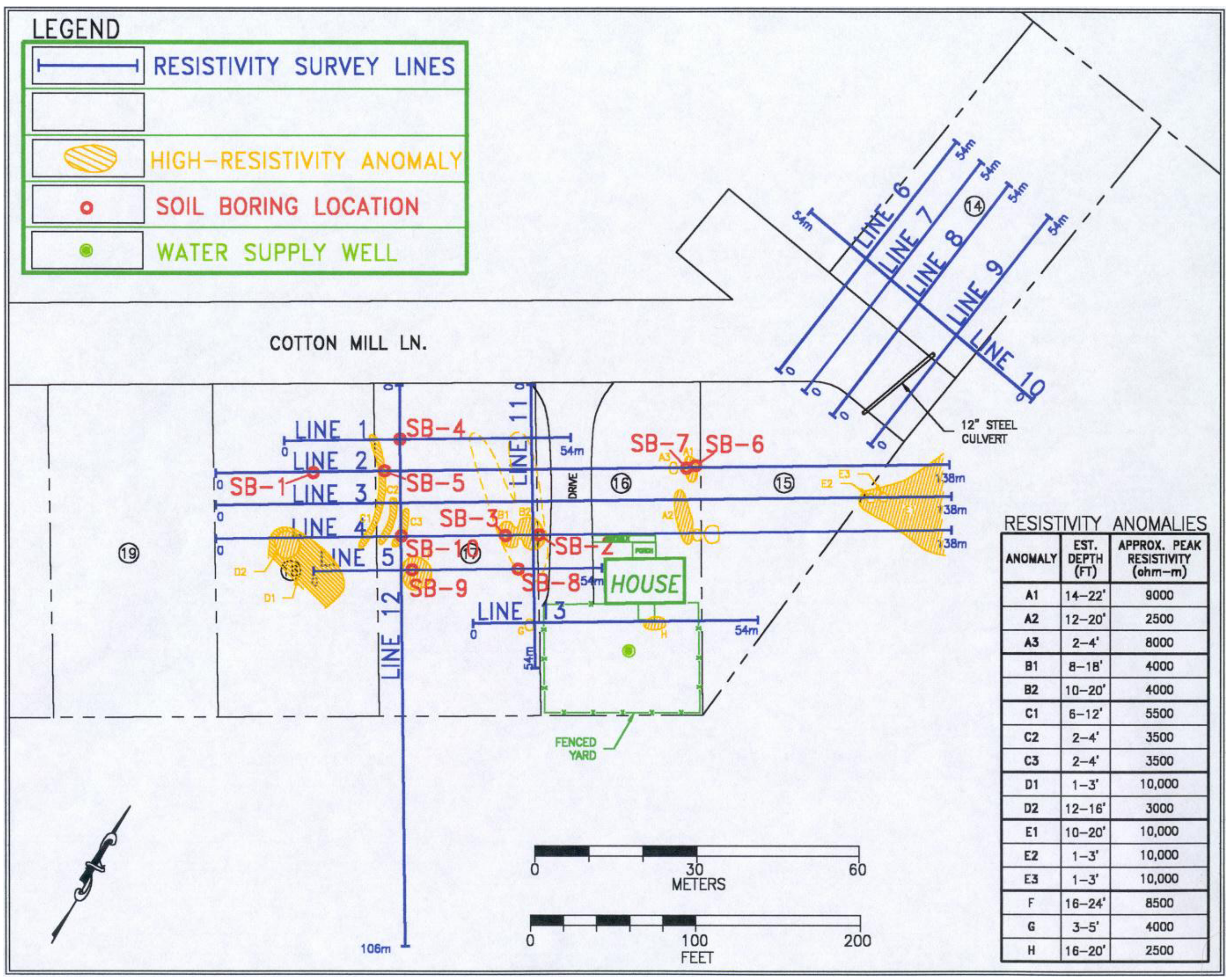
Pyramid Environmental and Engineering, P.C. ("Pyramid") is a full-service consulting firm specializing in environmental geology, geophysics, and engineering. North Carolina A & T State University ("NC A&T") is a historically black, four-year university with a strong commitment to the science, math, engineering, and technology (SMET) disciplines. Both are located in Greensboro, North Carolina.

The partnership between Pyramid and NC A & T began as part of the Talent 21 Program at NC A&T. The Talent 21 Program, funded by the National Science Foundation as part of its HBCU-UP program, is a comprehensive academic enhancement project designed to promote SMET careers among minority students. As part of the Talent 21 Program, NC A&T received funding to start an undergraduate research training program in geophysics. The purpose was to provide SMET students with opportunities to participate in practical, hands-on research projects which involved real-world application of physical science. Pyramid heard of the project and offered to help provide expertise, guidance, and student mentoring in geophysics. Pyramid committed to provide both staff time and resources beginning in August 2000.

The North State Gold Mine Project

In the late 1700s, gold was discovered in North Carolina and until the California gold rush in 1849, North Carolina was the only gold-producing state in America. Most of the gold deposits in North Carolina were played out by the early 1900s, although a few continued to produce into the 1940s and 1950s. There are a large number of abandoned gold mines in North Carolina which now present a number of environmental & geotechnical problems[1,2]. The North State Gold Mine in High Point, North Carolina was one of the more productive mines during most of the 1800s. It reportedly had shafts over 350 feet deep. Unfortunately, no maps or accurate records of the shaft locations exist. Today, the only signs of the former mine are several surface depressions believed to be mine entrances or vents and abundant quartz mine tailings[3].

The owner of a portion of the former North State Gold Mine land started the development of a small residential subdivision in the late 1990s. During the construction of a home on one lot, a void was encountered during digging for a foundation footing and another was encountered while drilling a well. It turned out that this lot and four other lots included portions of the former gold mine site (Figure 1). The developer contacted Pyramid to discuss using geophysical methods to look for potential voids on the property. Geophysical surveys can be fairly expensive, and the property owner could not handle the full expense, nor could he justify spending several thousand dollars on lots that were worth only about $20,000 each. We had to find a way to balance the time and money available for the project with the most efficient and effective ways to accomplish the primary goals. Because of Pyramid's relationship with NC A&T, we suggested that this project could be used as an opportunity for undergraduate students to participate in a geophysical research project.



ANOMALY	EST. DEPTH (FT)	APPROX. PEAK RESISTIVITY (ohm-m)
A1	14–22'	9000
A2	12–20'	2500
A3	2–4'	8000
B1	8–18'	4000
B2	10–20'	4000
C1	6–12'	5500
C2	2–4'	3500
C3	2–4'	3500
D1	1–3'	10,000
D2	12–16'	3000
E1	10–20'	10,000
E2	1–3'	10,000
E3	1–3'	10,000
F	16–24'	8500
G	3–5'	4000
H	16–20'	2500

FIGURE 1: Site map of North State Gold Mine study area showing resistivity survey line locations, resistivity anomalies, and soil boring locations.

NC A&T, through the Talent 21 Program, funded three students for the summer of 2001 and covered some of the costs of equipment for the project. In exchange, the property owner agreed to give NC A&T rights to use the data collected for student research and to allow the students to publish the results. He also agreed to allow his property to be used for future research projects. The property owner agreed to pay for Pyramid's time in planning and supervising the project and to write a final report, as well as for some time mentoring the students.

Preparing the Students

Three NC A&T students participated in the initial phase of research at the North State Gold Mine site. Two of the students were undergraduates: one of whom was a senior physics major; the other was a junior civil engineering major. The third student was a first-year master's student in physics. None of these three students had any previous coursework in geology or geophysics, although the graduate student had been exposed to geophysics when he had worked for an oil company during a previous summer. All three were minority students.

The first step in preparing the students for their summer research project was to introduce them to geophysics in general, and to the theory behind the geophysical methods we proposed using. This was done initially through a series of formal seminars which faculty and other students were also invited to attend. The first seminar focused on geophysics as a broad discipline and introduced a variety of geophysical methods, types of problems that can be solved using geophysics, and research and career opportunities in geophysics. Following seminars focused in more detail on the theory and practice of the most common geophysical methods.

While the seminars laid an important foundation and gave the students a framework to see how their project fit into the broader discipline, the details were given to them in several informal meetings. At these meetings, the students were introduced to the project and what they were going to attempt to do. The project was presented as a problem to be solved, with several options for how to go about solving it. Through reading assignments and discussions with lots of questions and answers, the students were led through the various methods that could be used and the rationale for choosing the DC resistivity profiling method. They were then given details of the resistivity method and how it was implemented in the field. We also discussed the design of the survey and the students helped decide what array geometry to use, what electrode spacing to use, and they helped lay out the profile locations on the site map.

Geophysical Survey Methods

The first phase of the investigation (Summer 2001) focused on the DC resistivity method. DC Resistivity has been used by several researchers to locate voids, caves, and similar features[4,5]. Different rock and soil types will exhibit different resistivity values. Clay-rich soils and weathered metamorphic rock typical of the North Carolina Piedmont are expected to have low resistivity. An air-filled void is expected to have a much higher electrical resistivity than the surrounding soils.

The purpose of a DC electrical resistivity survey is to determine the subsurface resistivity distribution by making measurements at the surface. These measurements are typically made by injecting electrical current into the ground through two current carrying electrodes and measuring the resulting voltage potential difference at two potential electrodes. The apparent resistivity ($\mathbf{p_a}$) is given by $\mathbf{p_a = kV/I}$, where **I** is the injected current, **V** is the voltage measured and **k** is a geometric factor related to the arrangement of the four electrodes. For this survey, we chose a dipole-dipole array (Figure 2).

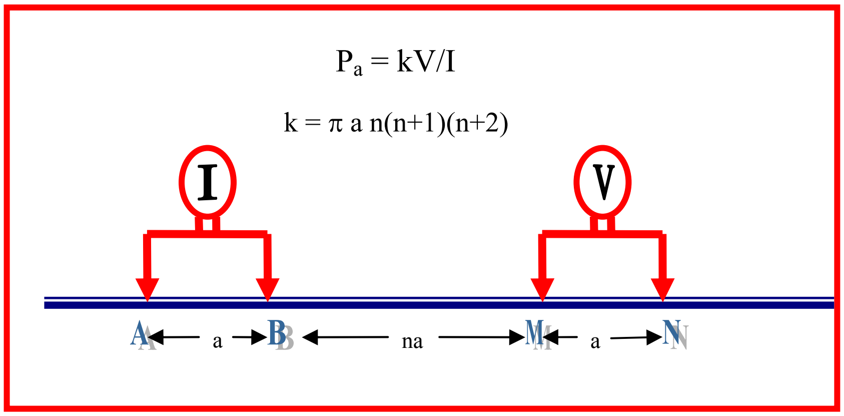


FIGURE 2: Dipole-Dipole Array for DC Resistivity Survey.

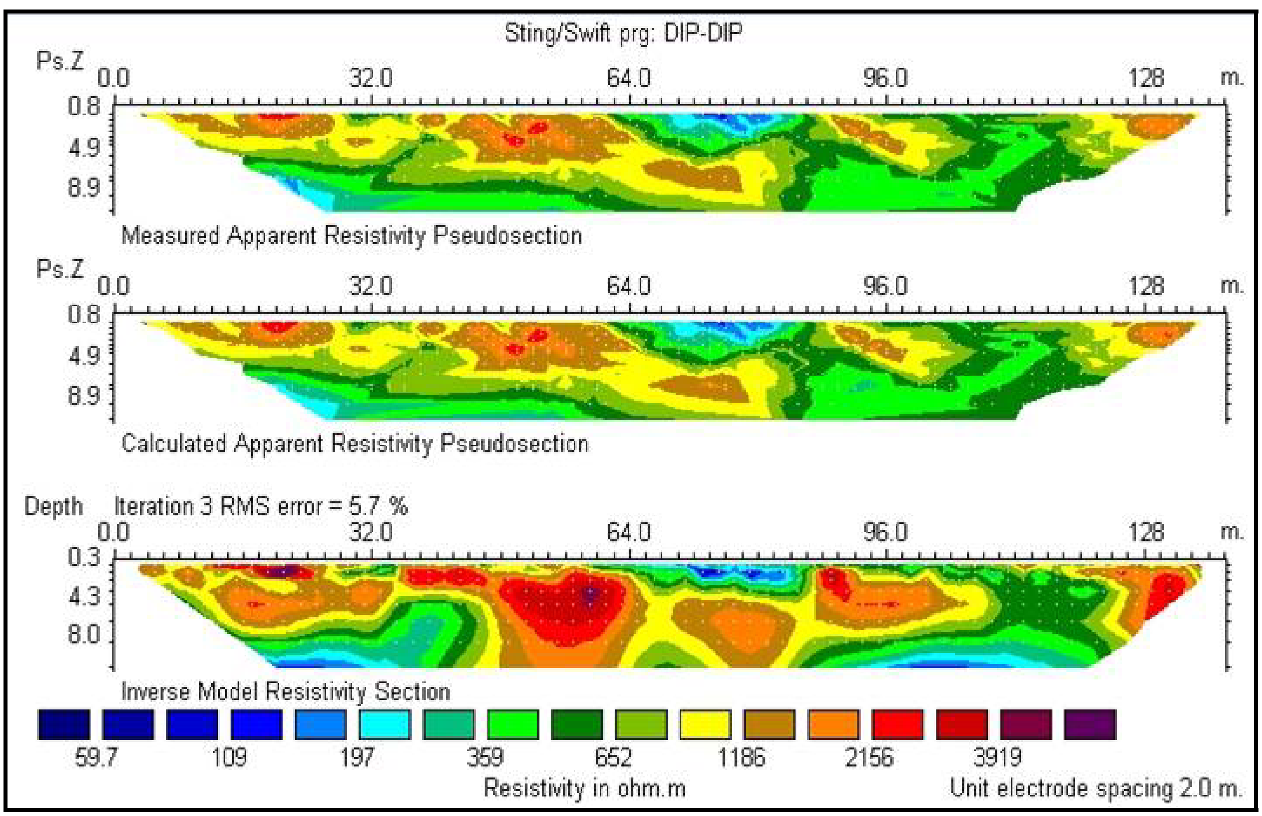


FIGURE 3: Inversion of Apparent Resistivity Data to produce Resistivity Pseudo-sections.

An individual resistivity measurement at the surface gives us the apparent resistivity along a flow path between the electrodes. The depth sampled by the flow path is dependant on the spacing of the electrodes. By taking resistivity measurements with a variety of electrode spacings were can determine the apparent resistivity at various depths.

To create a 2-dimensional resistivity profile, these measurements are repeated along a line of electrodes using various combinations of electrodes and spacing to produce a cross-section of apparent resistivity values. These data are then inverted to produce pseudo-sections of earth resistivity along the profiles (Figure 3). Both the resolution of the resistivity data and the depth that is being imaged are dependant on the array geometry, electrode spacing, and total length of the spread. With a fixed number of electrodes, shorter spacing gives better resolution but images shallower depths. In any case, the resolution decreases with depth.

Data Acquisition and Processing

In June 2001, the three students worked at the North State Gold Mine site under Pyramid's supervision (Figure 4) to collect resistivity data along several profiles covering the front portions of five lots. We used an AGI Sting R1™/Swift™ Resistivity system with a 28-electrode cable to collect the data (Figure 5). We chose a dipole-dipole array with an electrode spacing of 2 meters for a total spread length of 54 meters. This gave us a maximum imaging depth of approximately 10 meters. On profiles with multiple spreads we overlapped the spreads by 50%. We laid out 13 profile lines ranging in length from 54 meters (1 spread) to 138 meters (4 spreads with 50% overlap) for a total of over 900 meters of data. The locations of these lines are shown in Figure 1.

FIGURE 4: Three NC A&T students collecting resistivity data on site.

We only had the equipment for one week and we needed to maximize the amount of data we collected during that week, so we had to work as a team. Once a spread was set up along a profile location and the parameters input to the Sting/Swift system it took about an hour to collect a spread of data. We had two sets of electrode stakes, so while data were being collected on one spread, we would be setting up the next spread. Two people would measure out and set the stakes while the other two would survey their relative elevations using a surveyor's level and rod. When the first spread was finished, we would all work together to move the cables, reset the instruments, enter the parameters for the new spread, test the electrodes, and then start the data collection. Tasks were rotated so each student had ample opportunity to perform each task. It took six days working an average of about 10 hours per day for our four-man crew to collect all the data.

FIGURE 5: Sting Swift Resistivity System.

Over the next several weeks the students worked together to process the resistivity data and output the results, then they examined the results and looked at quality control data for each profile. Much of this time was spent learning to use the software. We used RES2DINV software[(6)] to perform a least-squares inversion of the data to produce pseudo-sections of the resistivity along the profiles. Some representative pseudo-sections are shown in Figure 6. By the end of the July, the processing, QC, and interpretation of the data were complete.

Reports & Recommendations

The three students worked together to produce a written report in early August 2001. The report summarized the purpose and objectives of the project, the theory behind the resistivity method, and the rationale for choosing that method, as well as the rationale for the design of the survey. The students then described the data acquisition and processing and presented the results of the resistivity survey and their conclusions. Afterward, Pyramid summarized the student's work and presented the data, results, and conclusions in a final report for the property owner.

Several high-resistivity anomalies were observed in the resistivity pseudo-sections that were interpreted as possible voids related to old mine workings. These anomalies are shown on Figure 1. Also, a broad zone of relatively high resistivity defining a thick structure dipping to the southeast was observed on lots 15, 16, 17, and 18. This was interpreted as representing the quartz dike with which the gold veins were associated.

Recommendations were made to the property owner to investigate the possible voids through drilling or excavation prior to doing any construction on the site. Several months later, the property owner brought a geotechnical drilling rig to the site and drilled on several of the anomalies. In at least one case, a pronounced, very high-resistivity anomaly (Anomaly A-1, Figures 1 & 6) turned out to be a vertical shaft that extended from 17 feet deep to at least 40 feet deep. In other locations the drill rig hit auger refusal before reaching the depth of the suspected voids. In the locations of some of the weaker anomalies, nothing was found by drilling.

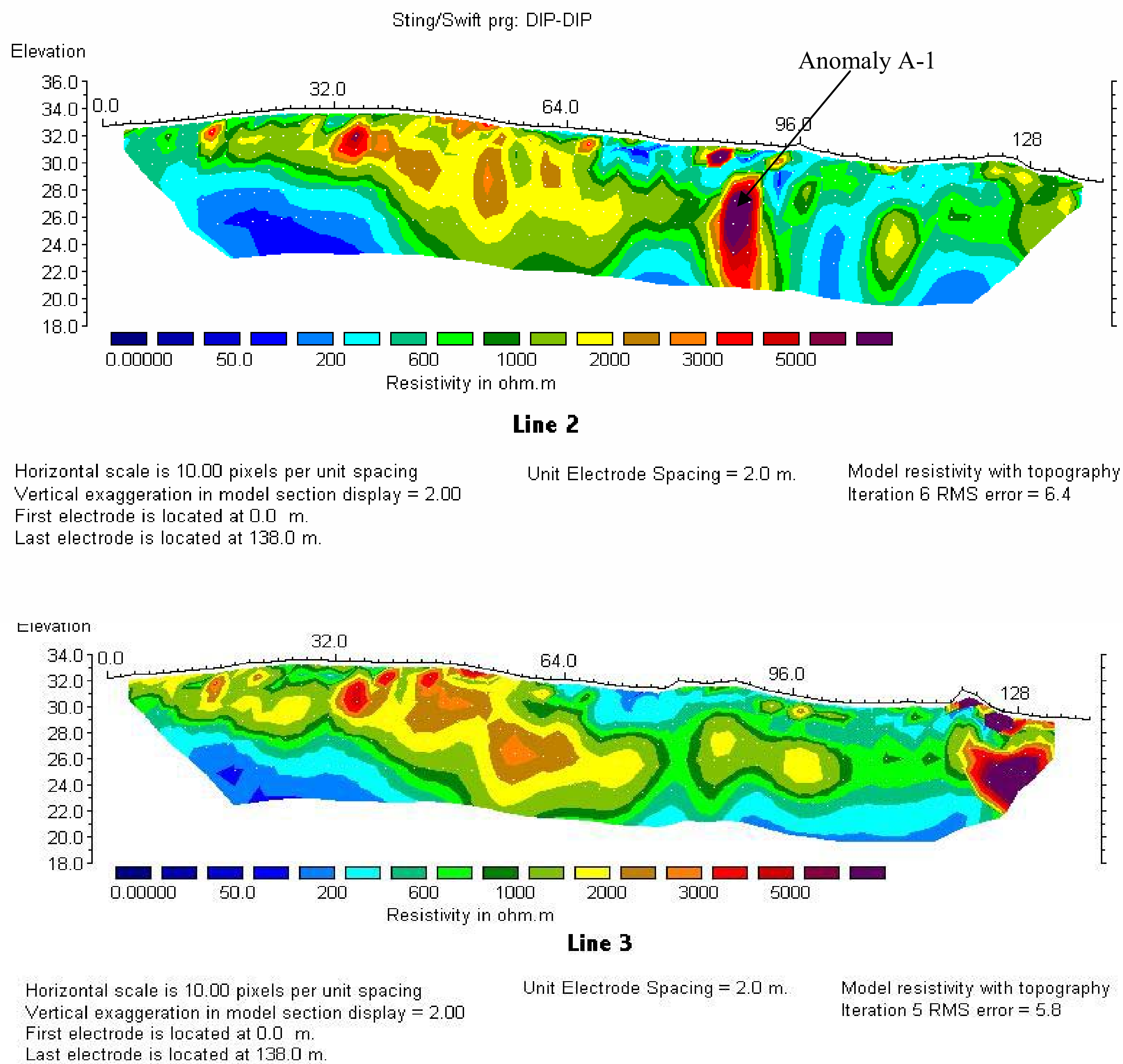


FIGURE 6: Resistivity Pseudo-sections for Lines 2 and 3.

Continuation of Student Research

The first phase of the North State Gold Mine project was concluded in August 2001; however, two of the students (the two undergraduates) continued to work with the data during the Fall Semester 2001 and they presented the results of their research project as a poster session at the NSF HBCU-UP National Research Conference in Albany, Georgia in February 2002. They won first place for their poster presentation at the conference.

During the Summer of 2002, as part of our Geophysical Research Training Program, six students returned to the North State Gold Mine site to try collecting different kinds of geophysical data. These students collected ground-penetrating radar (GPR) data and seismic refraction data along some of the same lines as the earlier resistivity data. One of these students teamed up with one of the original students from the previous summer and together they performed a new research project comparing the different types of geophysical data. This study was presented as an oral presentation at the NSF HBCU-UP National Research Conference in Tuskegee, Mississippi, in November 2002. This presentation took second place in their field. Also, these two students are finalizing a written version of the research paper that will be presented at the Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP) in San Antonio, Texas in April 2003.

Follow-up on Students

Of the three students who participated in the original North State Gold Mine Project in the Summer of 2001, all three continued to pursue research interests in geophysics. The graduate student completed his master's degree in Physics in the Summer of 2002 with a research project involving development of our Seismic Physical Modeling Laboratory at NC A&T. As noted above, both the undergraduate students continued to work on the gold mine resistivity data during the following semester, and one, along with another student from the Summer 2002 program, is still pursuing that research. These two students (one from 2001 and one from 2002) are both planning to enter graduate school and continue in geophysical research. The other undergraduate student from the Summer 2001 program graduated in Spring 2002 and is now a graduate student working with us in development of our Seismic Physical Modeling Laboratory.

Conclusions

The North State Gold Mine Project was a great success from several different perspectives. It was good for the property owner because he got a geophysical survey of his property at a significant savings and several potential voids were identified. This will be of great help in reducing risk for him or others who might try to build on the lots in the future, and this also benefits the community by identifying and evaluating potential risks on these properties. This was also a successful project for Pyramid as the property owner paid for most of Pyramid's time so it had a positive contribution to Pyramid's bottom line. The project also increased Pyramid's experience with the resistivity method and it has been a good project to use as an example for marketing. The University benefited from the project because a significant portion of the cost for the student research was born by Pyramid and the property owner and it has opened the doors for future research projects. Also, the project illustrates that industry involvement in the educational process can be of more than long term or esoteric benefit to industrial partners and can have immediate benefits to all concerned.

The greatest success of this project is in its benefits to the students and its impact in drawing students into ongoing involvement in research. All of the students came away with a positive research experience. They saw how the academic knowledge they gain in their studies can be used to solve real-world problems. They learned to work as a team to accomplish more than any one of them could have accomplished otherwise. Some of them gained the experience of presenting the results of their research in written, oral, and poster presentations at conferences, and they had the encouragement of awards recognizing the value of their efforts. The positive impact of this project is perhaps best seen in the fact that the students were encouraged by their involvement in this project to continue toward graduate studies involving research in geophysics. Thus, the North State Gold Mine Project fulfilled the main goal of the Talent 21 Program, to promote SMET careers among minority students.

References

1. Carpenter, P. A. III, 1972 (reprinted 1991). *Gold Resources of North Carolina*. North Carolina Geological Survey Information Circular 21, North Carolina Department of Environmental, Health, and Natural Resources. 33 p.

2. Clark, Timothy W. and Richard M. Wooten, 2000. *Report of Investigation – North State Gold Mine, Guilford County, North Carolina.* (DRAFT dated June 26, 2000) Carolina Geological Survey, Div. of Nat. Resources, Dept. of Environ. and Nat. Resources.

3. Reid C. Jeffrey, 2002 "Old Mines in North Carolina: Some Examples," Oral Presentation, October 15, 2002, Charlotte, NC, Association of Engineering Geologists, Carolina's Section Annual Meeting.

4. Wolfe, J. P, Richard H., Hauser E., and Hinks J., et al, 2000. Identifying Potential Collapse Zones Under Highways, in Proceedings: Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP-2000, Arlington, Virginia February 20-24), Environmental and Engineering Geophysical Society, pp. 351-358.

5. l-Behiry, M. G., and S. M. Hanafy, 2000. "Geophysical Surveys to Map the Vertical Extension of a Sinkhole: a Comparison Study", in Proceedings: Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP-2000, Arlington, VA, Feb. 2000), Powers, et al, eds., Environmental and Engineering Geophysical Society, pp. 341-350.

6. Advance Geosciences, Inc, (2000) "Geological Imaging 2D&3D" RES2DINV ver. 3.44 (February 2000), Volente Road, Austin, Texas.

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