AfricaArray International Geophysics Field School: Diversity and training come together in Africa

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Abstract

The AfricaArray International Geophysics Field School is a three-week program designed to introduce the complete workflow of a geophysical project. In the first week, participants design a geophysical survey of relevance to a mine, water-resource investigation, or an archaeology study. The design of the course includes considerations of cost and safety and is presented in a competitive manner. The weeklong data-collection phase ensures that participants are familiar with operation of all equipment, including gravity, magnetics, DGPS, resistivity, EM31, EM34, and reflection and refraction seismology. Data are processed in the evening, and safety issues are reviewed the following morning. The final week is spent on campus, interpreting and integrating data to form a coherent model of the subsurface. The participants are selected from three cohorts: University of Witwatersrand geophysics students, SEG Foundation and UNESCO-sponsored African participants, and U. S.-sponsored undergraduates attending as part of a Research Experience for Undergraduates (REU). Instructors include graduate students, resulting in a two-tier training system, as they learn about lecturing, logistics, and field preparation for weeks in advance. The field school has developed a wide-ranging network of geophysical talent throughout Africa, which is starting to seed new field schools.

Introduction — AfricaArray program and the Geophysics Field School

AfricaArray, a 20-year initiative started in 2004, is designed to promote, strengthen, and maintain a workforce of highly trained African geoscientists and researchers. AfricaArray is a wide offering of many programs, and details can be found on its Web site. Sustainable development in Africa depends on well-trained African geoscience professionals as the demand for Africa's natural resources grows and governments insist on the hiring of local talent. With this in mind, the AfricaArray Geophysics Field School (AAFS) targets academics, students, and government and industry employees who have been trained as geophysicists but lack significant field experience.

We are now more than 10 years into the AfricaArray program, and this is a good time to review this highly successful geophysics field school. The overarching goal of the field school is to learn to tackle geoscience problems with appropriate geophysical methods. This is accomplished by providing hands-on training in a genuine field setting, incorporating the whole geophysical workflow. We use a variety of geophysical methods (gravity, magnetics, resistivity, EM, reflection, and refraction seismic) to address real-world problems, such as loss of ground on a mine or overburden thickness at a building site. This geophysics field school plays a vital role in the transition of students to young professionals and is one of the few such schools worldwide to include external participants. Through the success of the AAFS, we are building a network of geophysical talent that is collecting geophysical data in the field, seeding new geophysics field schools in Africa, and providing critical development for Africa's resource sector.

"You provided me with the opportunity to acquire practical experience on methods, while back in Nigeria I would have only read the theories."

— Clement Onyekwelu, Nigeria

The need for field training

The need for geophysical surveys in Africa is readily apparent as exploration for hydrocarbons, minerals, and water — and the importance of geotechnical information — is rapidly expanding. However, few academic geophysics programs provide field schools because of limited equipment, lack of software, lack of dedicated personnel, expense, and liability issues. These constraints mean many students are only briefly exposed to geophysical fieldwork in a show-and-tell type of exercise, and many do not have experience with the full workflow of a geophysical survey.

With more students growing up in an urban environment, people frequently lack the camping and outdoor experiences that drew so many of us to careers in geophysics. Thus, many additional skills and logistics need to be considered for participants who are not familiar with camping and fieldwork safety measures.

"My time as an instructor was both enjoyable and challenging. The challenging part was that I had to prepare thoroughly for the lectures I would present to the participants, test the software and equipment, and understand the theory well to explain the different configurations of equipment in the field. Some of the participants held senior positions at their academic institutions, so I had to be professional in my approach by making sure that I assist them without trampling on their egos."

— David Ngobeni, participant and instructor, South Africa

Value of fieldwork

Perhaps more than any other discipline, the geosciences requires fieldwork and travel. Although small samples can be brought into the laboratory for further study, large-structure studies and data for 3D analysis must be collected in the field.

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This is often what has attracted people to the geosciences, along with the implied promise of travel. However, the value of fieldwork goes deeper, in terms of teaching concepts — fieldwork often helps to clarify difficult ideas. We often receive comments from participants that concepts such as aliasing are much clearer in the field after collecting their own data.

> *"It was as though we traveled to over 16 different countries every night, while just being in a room!"*
>
> — Ashley Anthony, South Africa

Participants

Each year, the field school hosts 30 to 35 participants. It is proving popular, and the selection process for the African participants is competitive, with more than 100 applications and inquiries received annually. We frequently must turn away a substantial number of strong applicant. This clearly indicates a need for practical, hands-on geophysics field programs in Africa. Participants have been sponsored with funding from the Society of Exploration Geophysicists (SEG) Foundation, UNESCO through the Swedish International Development Cooperation Agency (SIDA), the International Union of Geological Sciences (IUGS), the African Network of Earth Science Institutions (ANESI), and National Science Foundation (NSF) programs, including Partnerships for International Research and Education (PIRE), Opportunities for Enhancing Diversity in the Geosciences (OEDG), and Research Experiences for Undergraduates (REU) funding. The sponsor list varies from year to year, making our long-term sponsors extremely valuable in enabling us to plan consistently.

The core group of student participants is the Wits Geophysics Honors (fourth-year) class, which varies from five to 10 students. An additional group of approximately eight participants from all over Africa is selected on a competitive basis. In addition, a group of three to eight undergraduate minority students from the United States is selected. These students are part of an extended summer research opportunities program (SROP) hosted at Pennsylvania State University, with the goal of increasing diversity in the geosciences (Nyblade et al., 2011).

The total number of instructors is approximately 11, but it varies from year to year depending on the expertise available and on the number of volunteer instructors. Susan Webb, Ph.D., from the University of the Witwatersrand, coordinates the field school, and the academic, administrative, and technical staff members assist her. The field school has two tiers of instructors: the geophysics staff (Webb and Musa Manzi, Ph.D.) and graduate students.

This two-tier system enables the senior geophysicists to have oversight while giving geophysics graduate students a real chance to teach, learn logistics, and oversee the data quality for a particular method. Instructors learn as much when they participate as instructors as they did when they attended as students. Serving as a graduate-student instructor means taking complete responsibility for a single method. This entails making sure all of the background work is done — that the computers communicate with the equipment, the software is up to date, and the grid has been laid out on the computer and loaded into the GPS.

Many of the African participants are faculty members at their home institutions who are in charge of setting up field schools in their own universities. As part of a Penn State NSF REU initiative, several U. S. minority students participate with the goal of encouraging them to pursue higher degrees in geophysics by exposing them to an undergraduate research project in Africa. Their program starts before they arrive in Johannesburg and extends for some time after they return to the United States; it is a summerlong research experience for undergraduates, and the field component represents the data-gathering phase.

The wide range of participants' backgrounds results in a broad cross-cultural experience with many countries represented — field-school students have come from Botswana, Egypt, Germany, Ghana, Madagascar, Malawi, Namibia, New Zealand, Nigeria, South Africa, Tanzania, Uganda, the United States, Zambia, Zimbabwe, and more (Figure 1). Gender diversity is well represented, with an average of approximately 30% participation by women, which is well above average for geosciences in Africa. The strict selection criteria means all participants are engaged and everyone gets along in spite of the cramped quarters, late-night work sessions, and large age differences. We learn as much around the fireplace in the evening as we do in the field during the day.

We have involved industry in the field school by arranging several talks from specialists. In 2015, we concentrated on an entrepreneurial theme and hosted Dylan Morgan from Turris Geoscience, a consultancy based in Vancouver and Houston; Jeanne-Claire Trickett and Lindsay Linzer of MeerCat Geophysics, a Johannesburg-based seismic-interpretation

Figure 1. Countries of origin for African participants in the AfricaArray Geophysics Field School since 2005.

company; and Terry Odgers of Reddog, a Johannesburg-based geophysical supply and services company. They all gave ideas and tips about starting and surviving in your own business. We also had a special lecture from UNESCO representative Felix Toteu of Kenya on the many geoscience programs that UNESCO runs in Africa. In past years, we have hosted speakers from companies such as Anglo American, Anglo Platinum, De Beers, Schlumberger, and Shell.

The UNESCO and SEG Foundation grants have enabled us to reach our goal of hosting additional African students and leveraging this program to make it accessible to a larger number of people. This funding also allows us to provide teaching and supervision opportunities to graduate students. This is important in Africa because there are few opportunities for graduate students to take on meaningful teaching roles.

"During the 2012 field school, I learned how to process, interpret, analyze, and model the geophysical data. I was able to put into practice the theoretical skills I learned at the university. I can do magnetics, gravity, seismic, EM, and IP/resistivity surveys. This training gave me confidence in that in 2013, I was hired to do magnetics and EM in Zambia. In addition, I train undergraduate students."

— Lawrence Kabenge, Uganda

Location and schedule

The field school is loosely modeled on the U. S.-based Summer of Applied Geophysics Experience (SAGE) but runs on a smaller scale, with an emphasis on the African resource sector (see SAGE article by Baldridge et al. in this issue).

The field school starts with a trip to the UNESCO World Heritage Site at the Vredefort impact structure. This is the world's largest and oldest impact structure, one hour south of Johannesburg. There, the field-school participants are treated to spectacular outcrops of pseudotachylite breccia, overturned strata, shatter cones, and an overview of the dome and its geophysics (Figure 2).

Impacts are not generally considered to be of economic value; however, there are several notable exceptions. Sudbury is the world's largest nickel sulfide deposit and a small number of impacts in Phanerozoic sedimentary rocks host oil and gas reserves, so they are worth considering in an exploration program. Vredefort itself hosts several-dimension stone quarries — in fact, the stones seen in the Oliver Tambo Airport on arrival in Johannesburg are from quarries in the Vredefort impact structure.

The first week, from Monday through Thursday, is spent working on the "request for bid," lectures on safety and geophysical methods, learning software, forward modeling, testing equipment, packing, planning, and shopping. The GIS computer lab at Wits is large enough to host groups of as many as 27 students. Each student selects a particular geophysical problem for which to prepare a request for bid for a geophysical investigation. An example would be to design a ground magnetic survey to more accurately determine the properties of the magnetic dykes that cause loss of ground when mining. The instructors circulate in the room, helping students when not lecturing (Figure 3).

The students are also introduced to the various instruments and software they will be using during the following week and attend lectures on survey design, safety, and field logistics. At the end of the week, the students submit their request for bid on a strict deadline, which becomes the first component of their field-school mark. The students also present these proposals as teams in a "shark-tank" atmosphere, competing against each other to see who has the best proposal.

The second long week (nine days) is spent in the field, often on a mine property away from active mining, collecting a variety of geophysical data and focused on addressing questions such as: How thick is the overburden? Where are the geologic contacts? Is water associated with the dykes or fractures in the region? All these questions are important to mining operations and often impact directly on the safety of operations. In the field, we collect data with the following instruments: gravity (Scintrex CG-5), RTK DGPS (Trimbal), magnetics (Geometrics G856 and G858), resistivity (ARES system), refraction

Figure 2. An introduction to South African geology at the Vredefort impact structure by Lewis Ashwal, professor at the University of the Witwatersrand.

Figure 3. Field-school participants preparing their request for bids in the GIS computer lab at Wits University.

seismic (Geometrics Geode system), GPR, EM31, and physical-property measurements on core.

The students rotate through methods over a weeklong period so that every student runs every instrument individually. This enables us to host a large group yet ensures that the students handle all the equipment while keeping each group small (four to five people). We also spend a day at the core shed identifying lithologies in the area and measuring physical properties to be used in modeling. The students are required to field-process the data each night to assess the quality of the data and produce field maps of the results, which are presented in the morning at the "morning meeting." The morning meetings serve two functions: (1) They let the new group know what data has been collected the day before and (2) they give us a chance to review any safety concerns.

The students then spend the third week back at the Wits GIS lab, further processing the data, finding and correcting errors that were missed in the field using the notes from the field books, and preparing a presentation that integrates the results. On the last day, the students give a group presentation on their findings. This presentation is completed in one week to get the students used to time pressure; however, the instructors are available the entire time to help with the interpretations and problems that arise. Instructors also give lectures on various interpretation methods, software, and data-integration methods. The students' write-ups are in the form of a company report, and the best are submitted to the company sponsors.

The field course is successful in getting students started on realistic projects involving planning, collecting, processing, interpreting, integrating, and writing up a practical project. Because the students run all the instruments, collect, and process the data, they develop confidence in their abilities to initiate field programs and to quickly become familiar with equipment. The act of collecting and processing data in the field often makes complex classroom ideas clear. On several occasions, students have made comments such as, "Now I understand aliasing!"

Thus the goal is to enable the students to plan, execute, and report on a complete integrated geophysical project. For many, it is their first exposure to the full life cycle of a geophysical project.

"I have certainly learned a lot, not the least your tenacious adherence to safety issues. We shall be working hard over here to replicate the field school in Ghana and are confident to tap on your huge experience."

— Van-Dycke Asare, Ghana

Safety, maturity, and confidence

One of the great benefits of such a diverse pool of participants is that the groups are made up of people from different career stages, different countries, and different genders. This ensures that many skill sets are available within each group and much informal peer-to-peer learning takes place. Teams select a leader who ensures that safety and health protocols are carried out. Although many of the African participants have not previously encountered strict safety standards, most of the U. S. participants have grown up with a culture of safety. By having mixed groups, compliance with safety expectations is enhanced because the students will correct each other. For example, this is often the first time some participants have been required to wear seat belts. Having members of their group use them automatically makes it more acceptable. The goal is not to have students simply follow rules but to start to spot unsafe situations and confidently bring them forward at the morning meetings when each group is required to report on the previous day's work and safety incidents. For example, if someone forgot to bring a radio to the field, this is mentioned, and all groups make sure the radios are distributed. All incidents are discussed, and solutions are suggested and implemented. In Africa, we must compensate for a lack of personal safety equipment — we end up supplying most of the personal protective equipment (boots, vests, hats, goggles, and so forth).

Because many of our students have limited access to vehicles, we spend time on vehicle field safety. This includes learning how to properly hitch up a trailer, change a flat tire, and check the oil and battery. The field school is held in a safe, encouraging environment. Many students have had limited professional training, and a lack of "soft skills" greatly limits their employability.

Students are required to present repeatedly throughout the three weeks, first in the shark tank, then in the daily morning meetings, and in the final presentations. This gives the students ample opportunity to improve their presentation skills. Instructors are told to "keep their hands in their pockets." This ensures that they enable the students to be hands on and that they give only verbal instructions.

"I increased my knowledge in potential and geoelectric field methods which have enabled me to organize field camps successfully for local students in our chapter in Kenya. This has led to an increased buzz of geophysics and SEG in our university, making it one of the active chapters in East Africa. Finally, the experience gained has also enabled me to plan the first geosciences student conferences in our country and the third in Africa."

— Bogi Elly, Kenya

Data collection and results

During the week in the field, the students rotate among methods, learning to use a new piece of equipment each day. The equipment includes magnetics (both Geometrics G856 and G858 walkmag), Scintrex CG-5 gravity meter, Trimble DGPS, Ares multielectrode resistivity meter, Geometrics Geode Seismic system for refraction and reflection, GPR, and EM31. In addition, students learn to use handheld GPS and all the software necessary to process the data in the field (Figure 4).

In 2012, we collected a Wenner resistivity profile with the goal of determining the amount of overburden in an area that was slated to be mined with open-cast methods. This area is a choked valley, and the sediments have built up for a long time. In 2013, the same area was being mined, and we visited the pit. We compared our profile results with the open face of the pit. The profile was perpendicular to the pit face, and the depth to the fresh rock in the pit matched well with that measured in the survey. The variations in the bedrock /overburden interface have important implications for the cost of mining because it is significantly more expensive to blast fresh rock. Opportunities like this help students to understand the scale of subsurface mining and the value that geophysics can contribute (Figure 5) (Campbell, 2011).

In 2007, the magnetic data helped to define variations in overburden that were demarcated by significant changes in the sharpness of the amplitude of the magnetic signal. We confirmed these variations with data from boreholes in the area (Figure 6). The dykes that are imaged are a significant problem for the mine because they cause loss of ground to mining operations (Campbell, 2006). There is no platinum where there is younger dyke material. This example enables the students to estimate the amount of platinum lost and the cost to the mine.

Figure 4. Participants in the 2015 field school celebrate the end of the day with the EM31. From left: Linah Maphanga (South Africa), Hilary Korir (Kenya), Josia Shilunga (Namibia), Rocio Castillo (U.S.A.), Tsitsi Rakotondraibe (Madagascar), and Keoagile (Braza) Tshitlho, instructor (Botswana).

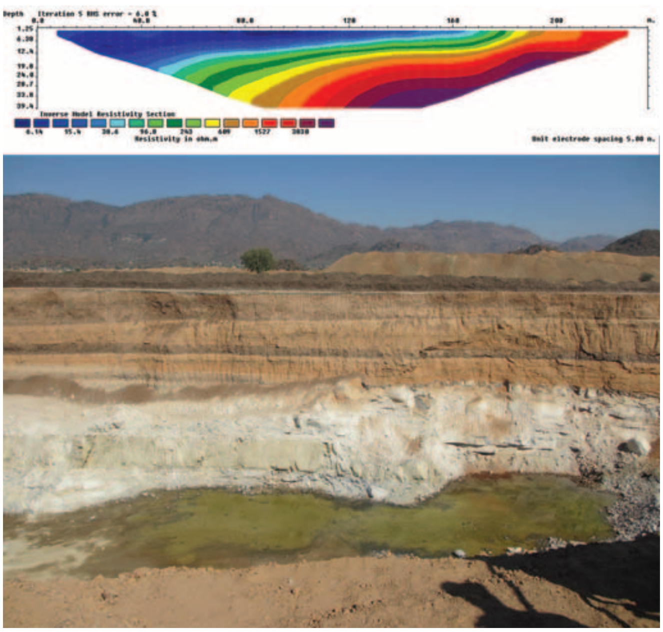

Figure 5. Open-pit mine with layered sediments in brown and fresh norite lithologies underneath. The resistivity line was collected the previous year perpendicular to the pit face at about position 150 m.

Our objective in 2015 was to map the extension of a fracture zone into an area of thick soil cover in the Vredefort impact structure. Gravity and magnetic data were used to help delineate this significant fracture zone in the field area (Figure 7).

This year, we were delighted that one of the students updated his blog on the field school. This is well worth the read (Bentley, 2015).

We also keep in touch with our past members and other interested friends of the field school via our Facebook page at “AfricaArray/Wits Geophysics Field School.” It isn’t all hard work in the field; the annual staff-versus-students soccer match is always a fiercely contested battle (Figure 8).

As the field school continues to evolve and take on new methods and locations, it is clear that the need for geophysical field training in Africa is as strong now as when we started the AfricaArray program in 2004. We are proud that several other geophysics field schools are getting started at universities in Africa, and we plan to continue to work with them to develop geophysical talent in Africa.

“I just want to say that this was a really worthwhile opportunity, and if I could go again, I certainly would. If there is anyone considering helping this initiative in some way, it is definitely valuable. Growing earth-science capacity in Africa is something that needs to happen; more people need to understand what and how earth sciences work and how valuable they can be for development. Things such as this field school are a great way to do this and should be encouraged.”

— Martin Bentley, 2015

“I can now assist my supervisor with a new magnetometer that we have received as a donation and teach my colleagues how to use it. Great thanks.”

— Vanessa Gaelle, Cameroon

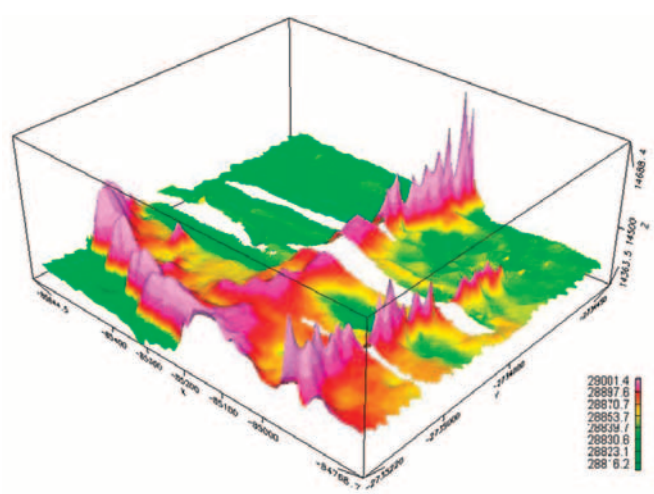

Figure 6. Magnetic data collected over intersecting dykes on a mine property. The change in amplitude of the magnetic signal clearly indicates a change in overburden thickness. Figure courtesy of Ralf Hansen, 2007.

Figure 7. Gravity data base station on a stable outcrop. From left: Vanessa Nana (Cameroon), Vanessa Eni (USA), and Sally-Anne Lee, instructor, University of the Witwatersrand.

Figure 8. Musa Manzi, Ph.D., University of the Witwatersrand, tries to score for the staff team in 2015.

Sponsors (past and present)

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