

The U.S. Geological Survey Paleomagnetism Laboratory at Fort Valley Experimental Forest—1970-1991

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Abstract—The United States Geological Survey (USGS) Paleomagnetism Laboratory was established in 1970, when Dr. Donald P. Elston of USGS negotiated with officials of the U.S. Forest Service in Flagstaff for the use of several buildings at the Fort Valley Experimental Forest (FVEF). The Fort Valley location was ideal for use as a laboratory, because its distance from Flagstaff mitigated the possibility of outside magnetic disturbance, which could affect any results obtained. It should also be noted that the necessary space was potentially available, in that most of the buildings were in states of disrepair and in danger of being torn down or moved. The USGS updated the buildings used by the Laboratory and helped ensure that the FVEF remained intact (Figure 1).



Figure 1. Main laboratory building at FVEF. (All photos courtesy of the Donald Elston Collection, NAU Special Collections, Flagstaff, AZ)

Introduction

Paleomagnetism is an important aspect of geology. It is the study of the Earth's magnetic history for the past billion-plus years (Archean-Pre-Cambrian to the present). Each rock has a "remanent" magnetization relative to the magnetic North Pole, which is imprinted when it is originally deposited. This "magnetic moment" can be preserved to the present, and is a tool for dating ancient beds by the position of the magnetic North Pole, and places them in time, in the history of the Earth. Thus a rock whose preserved magnetic position indicates that it should be in the middle of the Atlantic Ocean was probably deposited there many millions to billions of years ago. Careful selection and processing of rock samples permit the scientist to determine the latitude and longitude of the original formational location, which can be thousands of miles away from the sample's present-day location. Over the years the techniques have been refined so that the results have scientific legitimacy. The ensuing research papers have provided a fairly accurate map of the Earth's past history, helping to substantiate the theory of continental drift—movement of the continents throughout geologic time. Paleomagnetism allows Earth scientists to decipher our planet's past physical history (but not to predict its future!).

The studies begin with the collection of samples of rocks. First the geologist carefully chooses the rocks to be sampled. Flat-lying red sandstones, which are relatively iron-rich in magnetic minerals and unweathered, are generally preferred. This is because "secondary magnetization" can occur in rocks that have been exposed to the elements; also, rocks struck by lightning will definitely be remagnetized. Some igneous rocks, such as basalt, also yield good results.

Samples are obtained using a portable chainsaw adapted to drill rocks to obtain one inch-diameter cores in the chosen rocks, with a barrel whose cutting edge is encrusted with industrial diamonds (Figure 2). The drilling tools include a water can with pump to keep the core barrel relatively cool during the procedure. The cores (two to three inches long) are oriented, marked, labeled, and then removed from the holes and their numbers recorded. Then they are placed in individual sample bags, marked with this information, and numbered in ascending order. The sample marking tool (known as the 'scratcher') is made of brass as is the sample holder (or orienting tool). Finally, the small bags are placed in larger sample bags and their localities noted on the bags. The information is recorded in field notebooks to assure that all needed information is preserved (Figure 3).

The Paleomagnetics Lab at Fort Valley

The initial piece of equipment in the Lab was a spinner magnetometer built from a kit by Gary Scott, the first Lab employee and who later earned a PhD based on paleomagnetism research. The magnetometer (Figure 4) was

a rather primitive instrument. It required many procedures before any useful information could be obtained. Gary also constructed an "astatic" magnetometer (Figure 5), which, although it worked well enough, required darkness and was even slower than the air turbine spinner, so it was not used much (Scott 2008). A liquid-helium cooled super-conducting cryogenic magnetometer (hard-lined to a PDP-8 computer and later to an Apple II) with on-line plotters and printer was purchased in the early 1970s. Other equipment included a large low-field oven for thermal demagnetization.

When the cores reached the Lab many procedures were necessary before the results could be analyzed, studied, plotted, ruminated upon and reports finally written. The cores were first cut (Figure 6) to fit the superconducting magnetometer core-holders. Several measurements of each core were made and, for this magnetometer only, were simultaneously sent to an attached computer for recording; diagrams were plotted and the determination of position on a world map was done automatically. Data from the other magnetometers were recorded and inputted manually. If the results appeared "skewed," the cores were subjected to thermal demagnetization, and progressively subjected to temperatures up to 550 degrees F in an attempt to determine the original direction. It then became the task of the geologist to interpret, compile the many measurements and decide where to place more accurately the particular set of cores on the present-day world map. Igneous samples remagnetized by lightning could in some cases have the lightning-induced magnetization removed by applying progressively more intense alternating electromagnetic fields.

During many summers, staff at the Lab included graduate students from Cal Tech and other students associated with Dr. Eugene Shoemaker's paleomagnetism research projects. They learned the techniques necessary for evaluating their sampling results and at least two now have college laboratories of their own: Joe Kirschvink at Cal Tech, and Tullis Onstott at Princeton. David Van Alstine continued in the field, founding Applied Paleomagnetism, Inc. in 1986. Many others, including Michael Purucker, Duane Champion, Stephen Gillett, and Kenneth Tanaka, published their paleomagnetic studies and are still pursuing scientific careers. Other workers, for both Lab and fieldwork, were recruited from the earth science students at Northern Arizona University. They were hired under the auspices of a U.S.G.S.-subsidized program, M.P.E.S. (Minority Participation in the Earth Sciences) to encourage minorities and females to study earth science.

The Lab's first sampling expedition was a hike down the poorly marked Tanner Trail in Grand Canyon National Park in April of 1970. Elston, sons Geoff and Jay, and Gary Scott started down with food, water, drill, sampling kit, and high hopes. They emerged two days later with 30-plus samples (Figure 7). In the summer of 1971, a detailed magnetostratigraphic study of the Triassic Moenkopi sandstone at Gray Mountain, Arizona, was begun with Shoemaker, and Michael Purucker, a graduate student at Cal Tech. This study alone resulted in more than five major publications.

Figure 2. A core after cutting, ready for measuring.

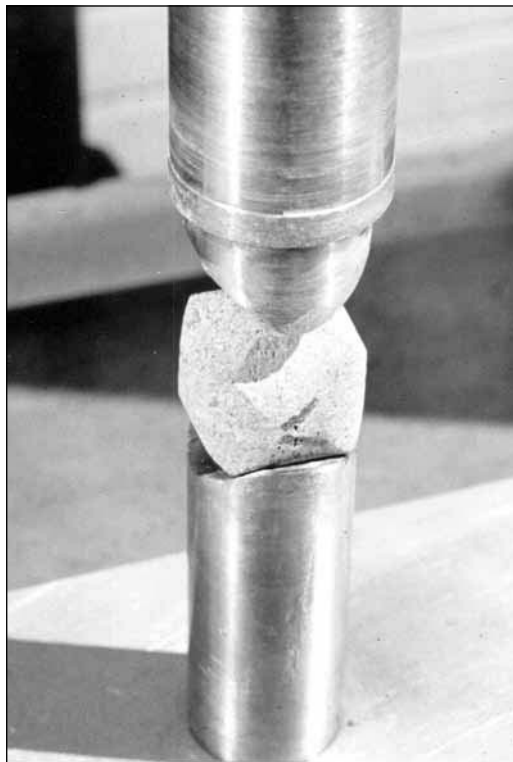


Figure 3. Sampling kit.

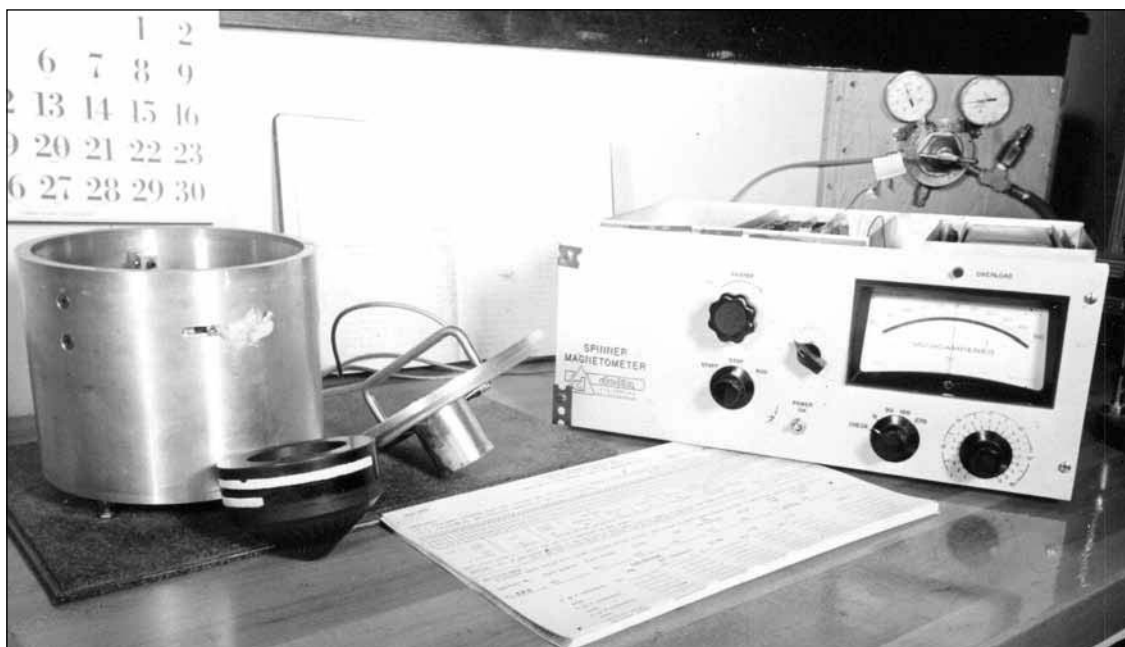


Figure 4. Spinner magnetometer.

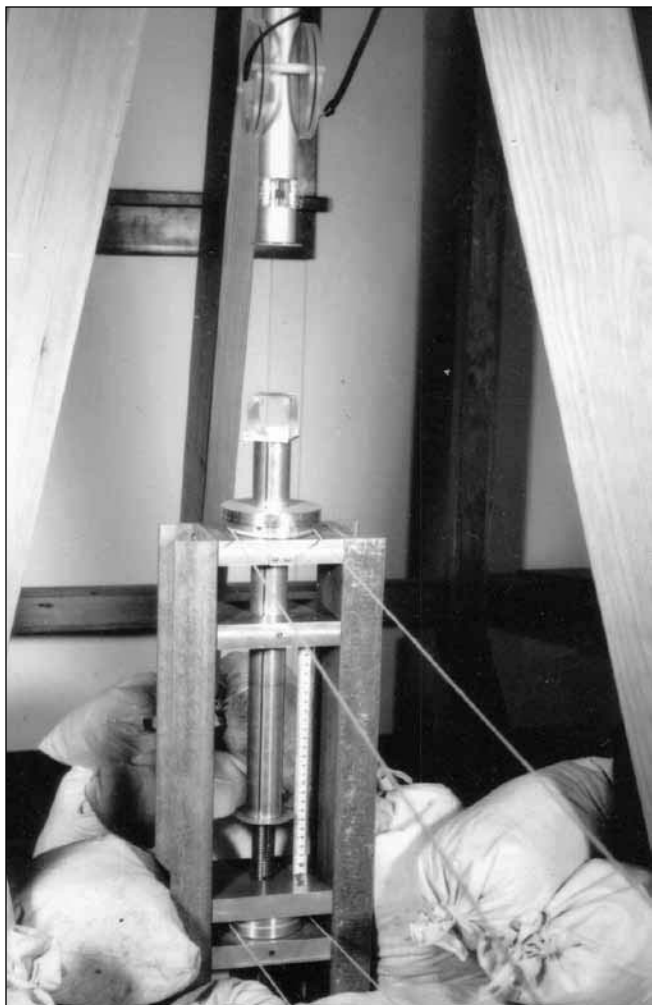


Figure 5. Astatic magnetometer.

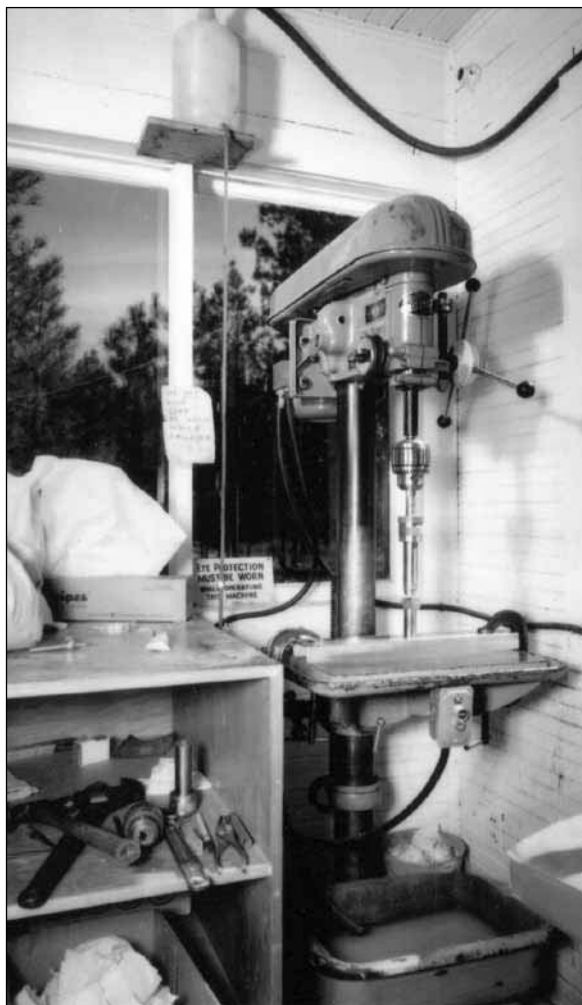


Figure 6. Core cutting equipment.



Figure 7. Easy access to outcrops is not a requirement. Don Elston drilling in the Grand Canyon.

At least eighteen research-river trips and one helicopter trip in the Grand Canyon (1972-1988) yielded thousands of core samples that were measured and worked on in the Laboratory (we thank the Grand Canyon National Park for permission to run research trips and sample in the GCNP). The river trips lasted about 18 days each with 15-18 people on a 225-mile journey down the Colorado River from Lee's Ferry to Diamond Creek. Stops were made at pre-determined locales where outcrops were sampled over the course of one to three days per stop. These studies focused primarily on the pre-Cambrian rocks, more precisely, the red Dox Sandstone, which is clearly visible from the eastern Canyon rim just under the "Great Unconformity." Some other Arizona localities studied were the Verde Valley-Hackberry Mountain area, the Devonian strata of central Arizona and the pre-Cambrian rocks of the Mazatzal Mountains, (a hiking, pack-horse trip because of the Wilderness status of the area). The resulting reports were published in peer-reviewed scientific journals. Two major publications should be mentioned: the "Guidebook to the Geology of the Grand Canyon" published in 1988; and in 1993, the Geological Society of America published Volume C-2 in the Decade of North American Geology Series, which contains three articles co-authored by Elston.

A National Science Foundation-sponsored project in the 1980s led to at least five sampling trips and collection of hundreds of samples from Taylor Valley, one of the so-called "Dry Valleys" in Antarctica. They were called that because the glacial ice does not accumulate there and the ground is barren most of the year. The samples were processed and reports were written on the samples, which were stored in the Elston freezer and transported to the Lab for measuring. Some of these samples were collected as described previously. Others were taken from cores drilled by the sampling teams in Antarctica during a cooperative project with New Zealand's Department of Scientific and Industrial Research—Antarctic Division (Figure 8). Additionally, samples were taken from cores drilled by the Dry Valley Drilling Project (DVDP). Results from Antarctica were published in U.S. and New Zealand publications.

Elston was involved in other foreign cooperative projects during the Lab's existence. He was invited to visit Hungary to study three continuous deeply drilled cores by the Hungarian Geological Survey (MAFI), and spent several months in Budapest, over the span of about ten years, working on the cores and preparing papers with his Hungarian counterparts. An invitation to China resulted in two sampling trips to North and South China, and preliminary results were published in Chinese. A project with several geologists of the USSR Academy of Sciences resulted in a month-long sampling trip to the Lena River in northern Siberia in the summer of 1988; results were not published because of time constraints.

The USGS Laboratory hosted many foreign scientists during its existence, including two from China who each spent six months processing samples obtained during the two sampling trips to that country. They lived at the FVEF while in the United States. Other countries represented were Hungary, France, and New Zealand. Samples from trips to Poland and



Figure 8. Drilling in Antarctica.

New Zealand did not result in publications because the information obtained was incoherent. The foreign guests from Hungary, China, and New Zealand now have paleomagnetism laboratories in their countries (France already had one) as a result of their visits to the FVEF. We like to think that the early contacts with China, the former USSR, and Hungary made a small contribution to the ongoing international cooperation among scientists of diverse ideologies.

The Lab operated until its closure in the fall of 1991. The physical equipment was transferred to the USGS facility at the Denver Federal Center, where it was used until 1995 when it was placed on the "surplus list" (Reynolds 2008). Elston continued his studies, and papers were published after his retirement, including a comprehensive paper on the Belt Supergroup of Montana and Canada in 2002. This was made possible by the very able contributions of, and collaboration with, Randy Enkin of the Canadian Geological Survey. The products of the Flagstaff USGS Paleomagnetism Laboratory were its publications, which contributed to the science of paleomagnetism, and the confirmation of the theory of continental drift. The papers on the Precambrian Grand Canyon Supergroup and Belt Supergroup of Montana and Idaho helped fill a void in the early geologic history of those localities.



A Magnetometer in place at FVEF headquarters.

Unfortunately few pictures were taken inside the lab during its history. The few existing are in the Donald Elston Collection at Special Collections, Cline Research Library, Northern Arizona University, Flagstaff, AZ. The collection was donated to the Cline Library after Dr. Elston's death in 2006, and contains slides and photographs of geologic interest in Arizona, Colorado, and adjacent states.

Acknowledgments

We thank Dr. Gary Scott, Berkeley Geochronology Group, Berkeley, CA, and Dr. Kenneth Tanaka of the U.S. Geological Survey in Flagstaff, AZ, for their reviews.

Author Information: Shirley and Carolyn are not geologists (we tell people who ask that we are geologists by marriage). We are good friends who first met in 1954, and were fortunate enough to have shared our husbands' lives in the office and field. We are proud and happy to collaborate in this report on subjects near to our hearts: paleomagnetism, polar wandering, continental drift, and, needless to say, field work.

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