The cover photo selected for this edition of *The Professional Geologist* depicts photographs of the Grinnell Glacier at Glacier National Park in Montana taken 81 years apart. A substantial difference between the two images is observed in the extent of the glacier. The USGS has several repeat photos of glaciers in the park taken during different years to show how the glaciers have changed. The website above is where the photographs can be found. Photo source: USGS 2019 (public domain)

The Wisconsin Section sponsored a Geology Day at the State Capitol in Madison on November 6, 2019. The event gave state lawmakers the opportunity to meet and talk with professional geologists about a variety of topics including: Wisconsin Geological and Natural History Survey, Geologic mapping in Wisconsin, Groundwater models, Responsible Metallic Mining - The Critical Role of Professional Geologists, PFAS and more...
FEATURES

Peer Reviewed - Mining
Game of Mines
Paul Fell

An Update on the Hydrogeology of Clayton Valley, Nevada
Danny Zampirro, CPG-10258, CA-PG.

Student Perspectives
My Summer Experience as a Stanford Undergraduate Research in Geoscience and Engineering, (SURGE) Scholar
Shirley Tsotsoo Mensah, SA-7566

Expanding Your Expertise Through Strategic Volunteering
Zachary Burton, SA-5138

Reflections on Change
Heidi Harwick, SA-9084

Advice to Students
Retirement Planning for Undergraduates
Peter H. Dohms, CPG-7141

Professional Affairs
Results of AIPG Climate Change Questionnaire
David M. Abbott, Jr., CPG-04570

Why Should Geologists Be Licensed? An ASBOG Perspective
Erick Weiland, CPG-6892, P.G. and Jason Patton, PhD, P.G.

More Advice to Students
Dear Geologists-to-Be
Ken Hnottavange-Telleen, CPG-10445

Success through Authentic Adaptability
James L. Gooding, MEM-3070

Classroom Earth
The Marvelous and Exotic Landscapes of Fjords
Stephen M. Battaglia, SA-5246

Designing a hands-on environmental sampling training course for students that meets the requirements of industry
Keith Torrence, Ph.D., CPG-11647 and Brigit Hagedorn, Ph.D.

Field Geology as Students, Researchers, and Educators
Ryan Shell, SA-7165, and David Peterman, SA-5297

Field Trips Link Students to Rock Resources
Michael T. May, Ph.D., P.G., MEM-0586
AIPG National Executive Committee

PRESIDENT - J. Todd McFarland, CPG
Wood Environment & Infrastructure Solutions, Inc.
O: (615) 577-7157, Tennessee Section
todd.mcfarland@woodplc.com

PRESIDENT-ELECT - Nancy J. Wolverson, CPG
Consulting Geologist
O: (775) 770-4615, Nevada Section
nancyjeanw@aol.com

PAST PRESIDENT - Keri A. Nutter, CPG
DOWL HMM
O: (907) 562-2000, Alaska Section
knutter@dowl.com

VICE PRESIDENT - Dawn Garcia, CPG
Consulting Geologist
O: (775) 770-4615, Nevada Section
nancyjeanw@aol.com

SECRETARY - Sara K. Pearson, CPG
Michigan Dept. of EGLE
O: (517) 420-3219, Michigan Section
pearsons@michigan.gov

TREASURER - Matthew J. Rhoades, CPG
O: (303) 359-1165, Colorado Section
rhaiodesgeo1@gmail.com

EDITOR - John L. Berry, CPG
John Berry Assoc.
O: (512) 452-8068, Texas Section
jibassoco@flash.net

ADVISORY BOARD REPRESENTATIVES
Stephen Baker, MEM
Operation Unite
O: (530) 263-1007, California Section
stevebaker@operationunite.co

Colin Flaherty, CPG
SME Inc.
O: (614) 705-2250, Ohio Section
colin.flaherty@smemeusa.com

Andrew Jones, YP
Patriot Engineering
O: (502) 961-5652, Kentucky Section
andrew.jones.geo@gmail.com

Shanna A. Schmitt, CPG
MN Pollution Control Agency
O: (651) 894-3513, Minnesota Section
shanna.schmitt@state.mn.us

YOUNG PROFESSIONAL - Erica L. Stevenson, YP
Michigan Dept. of EGLE
O: (586) 601-7985, Michigan Section
stevensonone@michigan.gov

PAST YOUNG PROFESSIONAL - Erica L. Stevenson, YP
Michigan Dept. of EGLE
O: (586) 601-7985, Michigan Section
stevensonone@michigan.gov

NATIONAL HEADQUARTERS
1333 W. 120th Avenue, Suite 211
Westminster, CO 80234-2710
7:30 AM - 4:30 PM MDT; M-F
(303) 412-6205 • Fax (303) 253-9220
aipg@aipg.org • www.aipg.org

EXECUTIVE DIRECTOR - Aaron W. Johnson, MEM - awj@aipg.org
ASSISTANT DIRECTOR - Wendy J. Davidson - wjd@aipg.org
PROFESSIONAL SERVICES MGR - Cathy L. Duran - cd@aipg.org
MEMBERSHIP SERVICES MGR - Dorothy K. Combs - dkc@aipg.org
OFFICE ASSISTANT - Christie J. Valero - cvl@aipg.org
OFFICE ASSISTANT - Kathy Giver - officeadmin2@aipg.org
AAG ADMIN ASSISTANT - Mona Scott - officeawi@aipg.org
AAG ADMIN ASSISTANT - Lauren Zeeck - office.aag@gmail.com

MEDICAL, AUTO, HOME, LIFE AND SUPPLEMENTAL INSURANCE
GeoCare Benefits Insurance Plan
Phone: 800-337-3140 or 602-870-4121
http://www.geocarebenefits.com/member.asp
E-mail: geocarebenefits@aglia.org

PROFESSIONAL & GENERAL LIABILITY INSURANCE
AssuredPartners of Colorado
Phone (800) 322-9773 (303) 863-7788
http://www.assuredpartnerscolorado.com

ALAMO RENTAL CAR - (800) 354-2322 - Member #BY-706768
AVIS RENTAL CAR - (800) 698-5685 - Member AWD #T003300
UPS Savings Program
www.aipg.org or www.savewithups.com/aipg
Use promo code WES462

American Institute of Professional Geologists (AIPG) is the only national organization that certifies the competence and ethical conduct of geological scientists in all branches of the science. It adheres to the principles of professional responsibility and public service, and is the ombudsman for the geological profession. It was founded in 1963 to promote the profession of geology and to provide certification for geologists to establish a standard of excellence for the profession. Since then, more than 10,000 individuals have demonstrated their commitment to the highest levels of competence and ethical conduct and been certified by AIPG.

The mission of the American Institute of Professional Geologists (AIPG) is to be an effective advocate for the profession of geology and to serve its members through activities and programs that support continuing professional development and promote high standards of ethical conduct.

AIPG Publication Policy, October 4, 2010. AIPG encourages submission of articles and editorials for publication in TPG on topics related to the science and profession of geology. Submittals shall be of interest to the members of AIPG, other professional geologists, and others interested in the earth sciences. Articles and editorials may be noted as follows at the discretion of the Editor, “The opinions, positions or conclusions presented herein are those of the author and do not necessarily reflect the opinions, positions or conclusions of the American Institute of Professional Geologists.” All materials submitted for publication, including author opinions contained therein, shall include accurate and appropriate references. The Editor has the authority to solicit, edit, accept, or reject articles and editorials and other written material for publication. The Executive Committee has the authority if it so chooses to act on any particular case to support or overrule actions of the Editor regarding the solicitation, editing, acceptance, or rejection of any particular article, editorial, or other written material for publication.

MORE FEATURES
It is the Greatest Love/Hate Relationship You Will Ever Have – Field Camp; an Experience no Student Should Ever Miss.
Valerie Smith - SA 1869

Radon: Invisible Killer.
Michael Urban, Ph.D. - MEM-1910 and Julie Curtis, Ph.D.

Mount Rainier (Washington): a volcanic landscape overflowing with geomorphological wonders!
Isaac E. Pope, SA-9950

Mining Mars for Gypsum
Breeanne Heudens, SA-10444

Peer Reviewed - Groundwater Models
Using Taylor Series to Assess Goodness of Groundwater Models
Grubaugh, K.E., Wilkins, B.D., Hromadka II, T.V.-AS-0020

50

DEPARTMENTS
3  Editor’s Corner
4  Letters to the Editor
5  Foundation of the AIPG
23  Tales from the Field
36  Executive Director’s Message
37  President’s Message
38  Test Your Knowledge
41  Professional Ethics and Practices
44  Educator’s Corner
48  AIPG Membership Totals
48  Professional Services Directory

Printed in U.S.A. by Modern Litho-Print Company in Jefferson City, Missouri.

For AIPG news and activities go to www.aipg.org.
By and for students – Learning from Nature, Character Traits, and Professionalism.

John L. Berry, CPG-04032

This is our student issue, and we have gathered the related articles together in three themes: Articles by Students, Advice to Students, and Classroom Earth. Two Peer Reviewed articles on mining topics constitute a fourth theme in this issue. One of these is about a Lithium mine, and the other a very careful one about positioning drill-hole samples in space and tracking them through the assay process in order to achieve meaningful results: advances in technology mean that this part of the mining business is much different and results are much more precise than they were in the days when I was lowering test tubes of hydrofluoric acid down boreholes in the African bush, but the potential for major data disasters is still there unless there are well-thought-out QAQC protocols in place. A third peer-reviewed article, from the group at West Point, concerns the use of Taylor series in assessing groundwater models: we also have a very good article on the hazards of radon in buildings.

The student articles are very varied: they deal with the practicalities of juggling study, work and family responsibilities (Harwick, p. 15), with grasping opportunities (Mensah, p. 13) or creating your own opportunities (Burton, p. 14; Pope, p. 51) to make connections and perform research, with the value of field camp (Smith, p.39). Our Classroom Earth theme also deals with field work, from the sheer excitement of teaching paleontology in the field and grabbing every opportunity to hunt fossils (Shell and Peterman, p. 31), to the organization of training courses in environmental fieldwork for indigenous populations (Torrence and Hagedorn, p.28) to the integration of a series one-day trips into the undergraduate curriculum (May, p.34).

The advice to students category takes a very long term outlook: Hnottavange-Telleen and Gooding (sidebars, p.24 and 25) emphasize character traits (trustworthiness), devotion to lifelong learning, flexibility and willingness to accept new responsibilities as keys to a successful career, whereas Dohms (p.16) focusses on the importance of starting to save as early in your career as you can, because life is an uncertain business. Like him, I can back up the importance of this with details from my own life: my late wife was diagnosed with a brain tumor shortly after we returned from my first job, in central Africa. I was still trying to restart my career in the USA, and the savings we had built up during 5 years in Zambia were critical in enabling us to survive that difficult phase. So I would add to Peter’s article that it is essential to maintain good health insurance: you never know what can happen, or when.

Every one of these “Student Issue” articles has something to offer, something that rewards a careful reading: the importance of trustworthiness, of ethical behavior, of being proactive in creating and grasping opportunity, of perseverance, of quickly attaining sufficient financial stability to weather unexpected setbacks, of keeping other options open. Every one of these comes down, in the end, to a character trait: responsibility, honesty, alertness, frugality, entrepreneurial spirit, willingness to go beyond duty.

I would add that being responsible includes contributing to one’s community and one’s profession: an investment in the affairs of one’s community makes life better for all of one’s neighbors, an investment in professional affairs not only helps to enhance the perceived value of your work, but it leads to an expanding network of trusted friends and mentors, and to the reward of knowing that in your career, as well as in your life, you have done good, as well as having done well. No-one can ask for more than that, and the time to start earning it is now, as a student!

Sermon over.

National Undergraduate Scholarship Applications Due February 1, 2020

Any student who is majoring in geology (or earth science), is at least a sophomore, and is attending a two-year or four-year accredited college or university in the U.S. can apply. Also, the student must be either a student member of AIPG or must have applied for student membership at the time the application for the scholarship is submitted.

Each student who is awarded a scholarship agrees, by accepting the scholarship, to prepare a 600 to 800 word article for publication in The Professional Geologist. The subject of the article must be related to a timely professional issue.

Details about the application process are available online at https://aipg.org. Click on membership then students to find the undergraduate scholarship instructions.

Application packet should be submitted to:

American Institute of Professional Geologists
Attn: Education Committee Chr.
1333 W. 120th Ave., Suite 211
Westminster, Colorado 80234-2710
(303) 412-6205 or e-mail: aipg@aipg.org
Response to Comments Received on President’s Column (Volume 56, Number 4)

My last President’s column in the Oct/Nov/Dec 2019 issue culminated in an ultimate question regarding the climate change conversation; “If not now, then when?” And several of the members that read the article accepted the challenge and sent me direct emails regarding their thoughts on my statements in that column. I do appreciate those that took the time to read and write to me about the article and to start the conversation; I am working to respond to the many emails I received but wanted to issue a common response through TPG.

That column, while composed of my thoughts and words, was written in a carefully curated way. As president, I do speak on behalf of the Institute, while also being charged with keeping AIPG relevant and useful to our members. I consulted with several other peers in AIPG from several different generations, fields of specialty, and varying positions on the topic of climate change to make sure that I was considering multiple sides of the conversation. While some of the emails I received in response to the column were supportive and others slightly more charged and passionate, I appreciate the support and the challenge to continue the conversation.

On the heels of that article, AIPG rolled out a climate change survey to gather information on the pulse of the membership regarding where they stand on climate change. A lot of helpful data was collected, and numerous comments received in response to that survey, which will help AIPG to craft a climate change position that best matches that of our members. David Abbott digests the climate change survey data on page 19.

A draft climate change position statement is currently being drafted and will be rolled out for review by the Executive Committee for the February 1, 2020 meeting in Raleigh, North Carolina.

Thank you all for your engagement, contribution, and passion – it is what makes AIPG the organization it is today.

Keri Nutter, CPG-11579
2020 AIPG Past-President

Hi Keri,

Thanks for your bold honest article in TPG re climate-change deniers. It is disappointing to me to have so many climate-change deniers at AIPG, it seems irrational until you look at the membership consisting of many old-time petroleum and mining geologists. But it looks hopeful that younger (and a larger percentage of females) AIPG members will bring AIPG into joining most geologists in acknowledging human involvement in climate change. One can’t try to solve problems until the problems are recognized and we all do our part to address the issues (right now we have electric outages in California due to the risks of wildfires from dead trees from our recent drought).

Thanks again.
George Reid, CPG-7597
Pleasanton, CA

Dear Ms. Nutter,

Very interesting article, but still too wishy-washy. Nevertheless, young, practicing geologists, such as yourself, looking for appropriate ideas on climate is encouraging. Keep thinking about it, because geologists have an ethical responsibility to come clean and be honest with the public about where we are in climate dynamics.

As an old grumpy, retired geologist, it seems to me that climate change is nothing new as has been around for billions of years. Regarding global warming, I believe is has been on the geologic books for the last 20 thousand years. So to me, I find nothing surprising, astonishing or even panicky about climate change or current global warming.

We are in one of the most dynamic phases of climate change - transition into interglacial, which means abundant global warming. Frankly, we are behind on the global warming schedule, because we are still coming out a glacial hiccup, called the mini ice age. Ironical-ly, this may have been caused by an ice free Arctic Ocean, which was no longer a desert, but a huge moisture pump. All one needs for an ice age is more frozen precipitation in the winter than melts in the summer. The temperature will adjust. It was warmer before the mini ice age, so man is helping the planet “catch up” by loading the atmosphere with CO2. CO2 is a favorite because we can model it, but it is worthless for climate predictability as the best CO2 models cannot come close to predicting known paleoclimates. Unfortunately, we cannot model H2O, especially in the chaos and complexity of interglacial transition.

Global warming has been very kind to man. Just image what a pain setting this continent would have been without it. Global cooling is not a good idea. The past mini ice age adversely affected Northern Europe’s agriculture and economy and ran the Vikings out of Greenland and North America.

I know these are unpopular ideas in
Building the Future of Geology
Support the Foundation of the AIPG

As you review your dues statement for 2020, please consider a donation to the Foundation of the American Institute of Professional Geologists. Every donation helps the Foundation to contribute toward building the future of geology. The Foundation supports a variety of programs of the AIPG that includes student scholarships, student and young professional workshops, educational programs aimed at practitioners, the public, and policy makers, and some special needs requested by AIPG or other professional organizations. The Foundation is proud to be able to serve AIPG and the geosciences by providing financial support for these programs. If you have any questions or comments about the Foundation, please contact me or any of the other Trustees of the Foundation for additional information. Your continued support is greatly appreciated. Thank you.

Barbara Murphy, CPG
Chairperson, Foundation of the AIPG
480-659-7131 office phone
bmurphy@geo-logic.com

The Foundation of the American Institute of Professional Geologists is a 501(c) (3) organization. Contributions and Gifts-in-Kind are tax deductible.

Letters to the Editor, continued

the science community. Looks like nobody sends money unless you are saving the planet. I appreciate the concern over man’s limited impact on the planet, but we are not going to slow down or stop the interglacial climate freight train.

Time to say what no one wants to hear. It is a bumpy climate ride, so buckle up. On a positive note, man has been very successful in adapting to climate change and I think man will continue to do so, no matter what we say - just look at what we are doing . . . adapting.

Best Regards,

Bob Traylor, CPG-10552
Texas

Hi Keri,

Like your article but feel the actual issue is being drowned out by the politics of the time. Anthropogenic climate change (not global warming) yes AND no. Margaret Venable article (page 10 TPG Oct.Nov.Dec 2019) compares David Abbots and Peter Dohms graphs BUT I like her modification of Abbott’s graph better because it does NOT “cherry pick” the time span but puts it in a broader perspective. Recently read an article that it is suspected there was once a habitable environment on Venus but has since deteriorated to inhabitable status. Do not think humans caused that. This planet has been around for a lot longer than us humans crawling around on it. We have not begun to see what this planet is capable of doing. Anthropogenic? not TOTALLY. A lot of our activities are NOT helping matters any but weaponizing climate change is NOT the answer. Yes we cause pollution and I am NOT in favor of fracking and so on and so forth, but the concept of climate change as absolutely man’s fault I do not agree with. That type of statement is an Absolutist statement and does not help matters. Those aspects that are anthropogenic need to be isolated and identified so that a manageable task can be addressed. The hysteria needs to stop. What do you think?

Mickey Ray Cruse, MEM-2105,
RG-0518
Missouri
Abstract

This article focuses on the need for Quality Assurance (QA) and Quality Control (QC) in relation to managing geoscience data within Mining and Exploration. QA and QC are sometimes used interchangeably but, of course, they are very different. QA is a quality framework or policy. It is those practices we put in place to ensure the quality of our data such as the type of certified reference material (CRM) to use and frequency of insertion into a sample despatch.

The emphasis for QC is to test and uncover errors to allow or deny acceptance. An example is a chart displaying analytical results together with control lines for a specific CRM for a laboratory analytical report (Control Chart). QA provides proactive measures. QC provides reactive measures. Together they are referred to as QAQC.

When quality controlling analytical results, there are three main areas of interest:

<table>
<thead>
<tr>
<th>Quality of Interest</th>
<th>Description</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>Closeness of a measurement to the actual (known) value.</td>
<td>Certified Reference Material (CRM). Known values in the elements of interest.</td>
</tr>
<tr>
<td>Precision</td>
<td>Repeatability of a measurement.</td>
<td>Paired samples taken at the same place and time.</td>
</tr>
<tr>
<td>Contamination</td>
<td>Contamination of a sample.</td>
<td>Blank. Samples with extremely low value or barren in the elements of interest.</td>
</tr>
</tbody>
</table>

The term QAQC, for some, implies QAQC associated with analytical results. But it should be broader than this. For example, the position of the GPS when taking surface samples is influenced by the number of satellites and their distribution in the sky. This is referred to as Dilution of Position (DOP). A low DOP value indicates the positional precision for the location is poor. Conversely a high value indicates reliability for the recorded coordinate.

Consider an idealized horizontal orebody, say 500m by 500m, 10m thick, depth to top of ore is 90m. We drill using Reverse Circulation (RC) to top of the orebody, and then diamond drill within the orebody itself. 1m cores are cut for analysis (Figure 1).

Regardless of the closeness of the drill spacing, and the size of drill bit used (PQ, HQ or NQ for example), the actual volume of core to the overall volume of an ore body is extremely small. Just over 0.002% for 12.5m spacing using HQ in this idealized example. Whilst the volume of data stored in a geoscience database representing this volume could run into the (tens or hundreds) millions of records, especially if a wireline geophysics program is undertaken, it still represents an extremely small snapshot of the ore body.

Although I have made assumptions about costs, and while this is theoretical, it is interesting to compare the magnitude of the amount expended to drill out our very small snapshot. Even at 12.5m spacing, in this example, costs are near $6,000,000 for over 160,000m drilled.

If the quality of the underlying data (the support) is suspect, it does not matter how sophisticated our geostatistical or modelling techniques are, any decisions we make are prone to significant risk. In the extreme, it could be the difference between mining when we should not be, or walking away from a project when we should be mining. Unfortunately, these extremes occur in the mining industry, as do the spectrum of problems which may ensue between these extremes.

Data is an asset. It has value, an intrinsic value, which is largely dependent on the costs associated with obtaining and managing this data. It would be an interesting exercise to assign an average (direct and indirect) cost for each sample in the database. This would provide some measure of its intrinsic value.

Data represents knowledge. For example, for mine start-ups, it will be used to prepare a bankable document. It represents our knowledge of the location, orientation, symmetry, geology and concentration of metal (for example) of an orebody and much more. It is the manifestation of the asset in the ground. We won’t know the degree to which our interpretations...
Desurveying computes the geometry of a drill hole in three-dimensional space based on the data contained in the survey table. There are a number of paths a drill hole could take through available survey measurements, but the physical constraints imposed by drilling are more likely to produce smoother paths. Selecting the desurveying method that gives the best likely approximation of the actual path of the drill hole will ensure that subsequent modelling is as accurate as possible (see Fig. 2).

Game of Mines

Figure 1 - Relationship between ore volume, volume of sample (when the sample is drill core of various diameters and hole spacing), and cost of acquiring the samples. Point on curves labeled with the drill-hole spacing, e.g. “25m x 25m.”

and modelling will be (in)correct until we finally mine it out (no model of an orebody can be completely accurate due to the small volume of samples relative to the orebody, as well as the many other uncertainties and limitations inherent in the data and modelling). It is therefore incumbent upon us to manage our data, our asset, in order to maximise potential, minimise risk for the benefit of stakeholders (investors, government and, equally importantly, our employees), and maintain our asset’s worth. Remember, whilst we may have a large volume of records, these still represent an extremely small volume of what is in the ground.

QAQC is our friend. A properly designed and enforced ‘across the board’ QAQC program, combined with an efficient geoscience information management system will assist with maintaining quality and minimise risk.

The journey of just one cored (or RC) interval from collection/sampling at the rig through to analysis and resource/reserve modelling is subject to quality risks at every stage of the way. As an example, are we confident that a sample (or geological) interval is correctly located in space?

- Has the orientation of the drill hole been validated? No unusual deviations down hole? If so, these will affect desurveying1 accuracy below this depth.
- Have downhole surveys been correctly adjusted for magnetic north and grid north?
- Have different downhole survey methods been used? Which one was used to desurvey and why? Is there some form of ranking to ensure the best ranked survey is used for desurveying?
- Were wireline surveys used? These are often related to magnetic north. Were they corrected to grid north, if this is the case? Was the tool correctly calibrated?
- How was the collar surveyed? If GPS, was DOP considered and, if low, resurveyed again at a different time (better distribution of satellites) or by a different method?
- Has the drillhole collar position been transformed from another grid? If so, were the down hole survey azimuths adjusted too? If the original grid is at an angle to the destination grid, the orientation of the drill holes is now wrong if not adjusted!
- What desurveying method was used? Tangential, Semi-Tangential, Balanced Tangential, Back Calculation, Split Segments, Spline, Other? Why? Is the method being used consistently? Each method produces differing results (Figure 2).

1. Desurveying: Desurveying computes the geometry of a drill hole in three-dimensional space based on the data contained in the survey table. There are a number of paths a drill hole could take through available survey measurements, but the physical constraints imposed by drilling are more likely to produce smoother paths. Selecting the desurveying method that gives the best likely approximation of the actual path of the drill hole will ensure that subsequent modelling is as accurate as possible (see Fig. 2).
Figure 2 - Example of a drill-hole desurvey, Top: Elevation (Section) through the surveyed drillhole. Bottom: Planview of the data. Each line represents the course of the drill-hole obtained by using a different interpolation method (see text).
The differences obtained with each technique are not huge (although Spline should never be considered), but locational variations down hole can be significant from a modelling perspective, especially in the case where location accuracy is of utmost importance, such as in many deposits to be mined by underground methods, or where there is faulting or knowledge of potential geotechnical issues. As I mentioned earlier, if there are uncorrected deviations part way downhole, this will wrongly place interval locations below this in space.

What about the risks introduced during logging, sampling and laboratory analysis, interpretations? As an example:

- Have your samplers been appropriately trained (not always the case). Do they appreciate the importance of unbiased sampling and the crucial role in the project that they themselves play?
- Are samples being appropriately and consistently taken? For example, for RC cuttings, are they being taken from the same discharge from the splitter, with duplicates taken from a secondary discharge. If not, bias is being introduced.
- Is the frequency of insertion of QC samples appropriate? Does your QC Geologist appreciate that geological variation (in the case of field duplicates) can pose significant challenges when quality controlling precision? (See discussion below).
- Are processes in place to ensure samples are not mislabelled or mixed up?
- Are CRM’s fit for purpose? Does the matrix of the CRM match that of the rock being sampled? Do they contain the elements of interest and in the expected grade range?
- Are the laboratory’s own reported QC results being assessed? These should not be ignored. They are important.
- Do you have sound analytical results QA procedures in place and are they being followed? Is there time pressure to get data in and to the modelers/mining engineers? Time pressures may well compromise the quality of your valuable data.
- Is the person making the QC assessments appropriately qualified?

A risk-ridden hazardous journey for just one sample. Most sites will have ‘across the board’ QAQC measures in place. Even so, these should always be reviewed and be assured that they are being maintained and rigorously applied. If you are concerned about QAQC, you may want to consider joining a LinkedIn Group such as:

**QAQC in Mining, Exploration and Processing** to share your knowledge and experiences and to learn from others.

Finally, I will focus on the impact of geological variation when assessing precision, because this, in my view, is not fully appreciated when quality controlling precision.

Consider a manufacturer of soft drinks who wants to quality control the precision of volume of liquids inserted into bottles. Their product is homogeneous. Sampling conditions are controlled. The number of samples they take and the frequency they are taken is unlimited.

Contrast this with the challenges presented in Mining and Exploration. Samples and sampling differ markedly from that in manufacturing:

- Heterogeneous product (geological variation is significant)
- Differing sample types (core, cuttings, stream, soil, etc.)
- Different sampling methods.
- Different sampling/preparation stages (field duplicates and duplicates of the crushing, pulverizing, instrument repeats, etc stages).
- Limit of two samples only (usually) for each stage evaluated by paired data (duplicates).
- Different analytical methods.

Without a proper quality assurance program and supporting quality control, errors of these types would be missed. Geological variation is the largest consistent contribution to error.

A field duplicate, despite our best efforts, is not a duplicate. It is as close to a duplicate as we can achieve (semantically, these should be referred to as field pairs). However, the product (core, cuttings) may be so variable, because of lithology, mineralogy and/or alteration, that no effort can produce a ‘duplicate’ in the sense required for quality control. We must always be mindful of this when quality controlling precision. It may not be the laboratory that is at fault. It may not be a sampling issue on site. When QC ‘failures’ are received, one should always consider reviewing the logged core descriptions, or reinspecting the core, with the goal of evaluating the inherent geological variation that may have contributed to the ‘failure’.

How can the effects of geological variation be reduced? One way would be to homogenize before splitting into paired samples. However, this may not always be practical.

I hope this article generates some reflection concerning QAQC at your site. In the past, I have worked in resource modelling for BHP (Yarrie Iron Ore, Cannington Pb-Zn-Ag) and various other geoscience positions. I know only too well the importance of data quality.

### About the Author

Paul obtained a first class Honors Degree in Structural Geology from Macquarie University, Sydney in 1984, then worked in resource modelling and data analyst roles for organizations including BHP Minerals Pty Ltd and BHP Iron Ore Pty Ltd. After spending 15 years with acQuire Technology Solutions, guiding their learning solutions and acting as QAQC Advisor to staff and customers, Paul has recently formed his own Consultancy, focused towards the management of geoscience data.
An Update on the Hydrogeology of Clayton Valley, Nevada

Author
Danny Zampirro, CPG-10258, CA-PG, Division of Water Resources, State of Nevada

Abstract
This paper seeks to update and expand upon a previously published paper on the hydrogeology of the Clayton Valley lithium mining operation in Esmeralda County, Nevada. Water Rights are a critical and necessary component of the mine in order to pump lithium rich brine from the subsurface into solar evaporation ponds. Brine is passed through the pond system as grade increases before processing strong brine into lithium carbonate. The primary ash aquifer (Main Ash Aquifer) of the Clayton Valley has been the principal source for lithium bearing brine since 1966. Its history is now better understood with geochemical correlation performed on a sample taken from a well during construction in order to determine if it is from the same eruptive event as the Long Valley Caldera/Bishop Tuff in Mono County, California.

Introduction
Clayton Valley is home to the only lithium chloride/lithium carbonate producing property on the North American continent and resides in southwest Nevada, in the Basin and Range province (Figure 1). The source paper for this update was presented at the Proceedings of the 39th Forum on the Geology of Industrial Minerals, May 18-24, 2003, hosted by the Nevada Bureau of Mines and Geology (NBMG). The proceedings volume for the 39th Forum were published as Special Publication 33 in 2004 by NBMG (Zampirro, 2004). The following year, this same paper was peer-reviewed and published by the American Institute of Professional Geologists (AIPG) in their May/June 2005 publication, The Professional Geologist (Zampirro, 2005). Water rights information in this update is largely from the State Engineer’s (SE) Office, Nevada Division of Water Resources (NDWR), Department of Conservation and Natural Resources.

Water Rights
Water Law in Nevada follows the Prior Appropriation Doctrine. The three basic tenants are:

1. First in time, first in right with a Permit. Senior (older) priority rights trump junior priority rights.
2. Beneficial use is the limit of the water right (Certificate).
3. Use it or lose it. Water rights can be cancelled, forfeited or abandoned for non-use.

The data contained herein are sourced from the water right permit files.

Albemarle U.S., Inc. is the current owner/operator of the Clayton Valley deposit. The four years this author resided at the property as Wellfield Supervisor/Hydrogeologist was from 2000 through 2003, when it was owned and operated by Chemetall-Foote Corporation.

Each basin in the State of Nevada has a perennial yield assigned to it. Perennial yield is the estimate of groundwater that can be extracted from a basin each year, through time, without depleting the basin’s groundwater reservoir. The

Figure 1 - Location Map for the Lithium Brine Operation in Clayton Valley, Nevada
sources of data are U.S. Geological Survey (USGS) Bulletins and Open File Reports, which started calculating perennials yields throughout the state in the 1940s. Clayton Valley has a perennial yield of 20,000 acre-feet annually (afa).

According to data contained in the permit files, Albemarle has approximately 20,000 afa titled in its name. The hydrographic basin (Clayton Valley, basin 143) manner of use in “mining and milling” is permitted at about 21,280 afa, which includes the Mineral Ridge Gold property above the playa to the west, in the Silver Peak Range.

Over the life of the mine, there were periods when the economic value of lithium carbonate and its downstream products was so low that wellfield production was reduced in order to lower site costs. I believe this contributed to lower average pumping rates, such as during 2009, when the recession was getting started. However, in the last few years lithium has become more popular than ever. Lithium is the lightest metal, and as far as this author knows, has the highest charge to weight ratio, making it an ideal, lightweight, critical component of a variety of batteries.

When economics and management demand required increased production, the delay in ensuring maximum wellfield output and finished product could be as long as two years. This is largely due to the slow evaporation process through the pond system (Figure 2). Compounding this delay further would be the need for an increased budget for contracting a driller, drilling, outfitting the well and producing to the pond system. This might add another six months. Since this boom market has emerged so rapidly, recent wellfield production has been above the past averages.

**Main Ash Aquifer**

The origin and age of the MAA has long been a subject of interest to Clayton Valley mine geologists. Its existence is the fundamental basis for the storage and transportation of a major portion of the brine that has been extracted from basin wells since 1966 (Figure 3). Once the ash was better understood lithologically, identification as a marker bed and aquifer became easier. It was frequently encountered at about 250 to 300 feet below ground surface. Some of the earliest borings were within two miles of the town of Silver Peak (near center of Figure 1), versus the far east-northeast edge of the playa-wellfield, where the dirt road rises off toward distant Goldfield. Eventually, exploration borings and wells were constructed further and further to the east-northeast, where the Cross Central Fault (CCF) was encountered and passed (Figure 1).

As understood early on, the MAA was a nearly flat-lying ash bed between about five and as much as 30 feet in thickness. In time, it was more typically encountered at about 350 to 400 feet, gently deepening to the east. As drilling and exploration moved past the CCF, the depth to the MAA was becoming deeper still. Indeed, the further drilling progressed to the northeast, the greater the indication of down-drop in this region of the basin. This drilling and dutiful logging by staff geologists over the years led to a significant, developing discovery in understanding the faulting and displacement of the basin. The lithologic data was not necessarily reflected in well drillers’ logs, but much more accurately in the wellfield geologists’ logs.

Other less extensive, discontinuous ash beds exist in the basin that are below the MAA, namely the Lower Aquifer System (Figure 3). The existence of ash in this aquifer is not as well understood as its brine yielding characteristics. What event(s) brought this ash to the basin? Age dating of this ash and discovering its origin would be intriguing.

Based on targets historically identified by staff personnel, it is estimated that a few wells have been completed into the Lower Gravel Aquifer system since 2004 (Figure 3). This is the bedrock/alluvium interface of the down dropped block, with wells perhaps as deep as 1,700 feet or more and exploration borings deeper still. Finding suitable well sites is possibly becoming more of a challenge as the wellfield ages. Pressurized drilling such as reverse circulation can send cuttings and drilling fluids out into strata where they can encounter older
boreings or weak formations that fracture and vent to the surface, giving drillers considerable difficulty with progress and returns. This was encountered a number of times. Active well count is likely still in the 50-range, tapping all six known aquifers.

Much of the time utilized by the wellfield maintenance crew is spent in keeping transfer pumps, existing wells, and well-pumping units in good working order—no small task with the harsh environment, high TDS, and salt-rich brine playing havoc on equipment, well casing, meters, and the like.

Correlation of the Tephrochronology of the Main Ash Aquifer and Bishop Tuff

The Long Valley caldera eruption of the Bishop Tuff near Mammoth Mountain in Mono County, California is well documented. The now confirmed, subsequent ash deposition in Clayton Valley was geochemically correlated after the original publication of the paper. Chris Henry of NBMG was able to send an ash sample we collected from well FM-381 at 710' for geochemical correlation to Mike Perkins of the University of Utah for analysis (Perkins, M., written communication, 2006). The sample analyzed was a direct geochemical match to the Bishop Tuff, confirming the long-held belief of employees and fellow geologists that the Main Ash Aquifer is indeed the ash fall from the Long Valley caldera/Bishop Tuff eruption (Fig. 4). Crowley et al. (2007) reported a date of 767,100 ± 900 years for the Bishop Tuff by 206Pb/238U dating of zircon.

Lithium Source

It is believed by many, including this author, that the felsic volcanics in the southeastern portion of the Clayton Valley are the primary source of lithium in the Clayton Valley. Price et al. (2000) demonstrated lithium values are significantly elevated in the surrounding Tertiary obsidian and rhyolitic flows of the Montezuma Range and the ash-flow tuff in the Clayton Ridge hills west of the Montezuma Range. Values observed from numerous samples taken throughout the area indicate, through unit volume calculations, that ongoing leaching and weathering from these volcanics combined could have yielded enough lithium to produce the values estimated to be contained in the basin, based on historical production and reserve estimates. The average sample value, including devitrified, oxidized and weathered samples was 106 ppm, with the highest value 228 ppm, distinguishing the Montezuma Range as one of the richest rhyolites in the world. MacDonald et al. (1992) analyzed 160 rhyolite samples from around the world, with an average Li content of about 58 ppm, excluding one sample.

Summary

Water rights are required for the mine in order to pump up to 20,000 afa of brine into the pond system for upgrading by solar evaporation. This process may take up to two years before the brine is of sufficient strength in lithium chloride. Strong brine is then pumped about three miles up to the plant in Silver Peak for processing into lithium carbonate. The MAA has been a primary source of the lithium rich brine and has its origins in the Long Valley Caldera eruption in Mono County, California. Ash from this event covered much of the western United States. The MAA has been the type section and marker bed for the property and provides an ideal means of storing and producing the desired lithium bearing brine. Geochemical correlation of the MAA and the Bishop Tuff was confirmed in 2006 by geochemical analysis, confirming long held beliefs that the Bishop Tuff is indeed, the source of the ash in the MAA.

Acknowledgements

I would like to express my gratitude to Joe Potseega and to Jon Price, Nevada State Geologist Emeritus, for his encouragement and editing. Thank you Chris Henry (NBMG) and Michael Perkins for following through on having the ash samples analyzed, and thank you to my wife, Susan Renee, for her patience and eternal support.

References


Perkins, M., 2006, written communication, University of Utah.


Strong brine is then pumped about three miles up to the plant in Silver Peak for processing into lithium carbonate. The MAA has been a primary source of the lithium rich brine and has its origins in the Long Valley Caldera eruption in Mono County, California. Ash from this event covered much of the western United States. The MAA has been the type section and marker bed for the property and provides an ideal means of storing and producing the desired lithium bearing brine. Geochemical correlation of the MAA and the Bishop Tuff was confirmed in 2006 by geochemical analysis, confirming long held beliefs that the Bishop Tuff is indeed, the source of the ash in the MAA.

Acknowledgements

I would like to express my gratitude to Joe Potseega and to Jon Price, Nevada State Geologist Emeritus, for his encouragement and editing. Thank you Chris Henry (NBMG) and Michael Perkins for following through on having the ash samples analyzed, and thank you to my wife, Susan Renee, for her patience and eternal support.

References


Perkins, M., 2006, written communication, University of Utah.

Shirley Tsotsoo Mensah, SA-7566

If you ever get the opportunity to participate in a National Science Foundation Research Experience for Undergraduates (REU) program, do not let that opportunity go! First off, do not doubt yourself and the possibility of getting accepted into the program and just put in the application! This was my experience this past summer; I got the opportunity to participate in the Stanford SURGE 2019 program, which to me was not possible at the start of my application. Especially as an international student, I did not even expect to pass the first round of application reviews. The selection process was a two-month long rigorous process comprised of an application form with 4 essays and questionnaires, a math aptitude test, and two phone and/or video interviews. Am I going to get in? Do I qualify? These and many more were the questions that ran through my mind every day of these two months. But I did and enjoyed every part of it!

SURGE was a very involving and enriching experience. I not only gained exceptional research skills and scientific knowledge in the paleoclimatology field, but also gained several opportunities for networking and professional development. I would do this all over again if given the chance. I worked with the Terrestrial Paleoclimate Research Group, where we studied the coevolution of climates and ecosystems during the Cenozoic in the John Day region, Oregon, USA. Our focus was identifying changes in climate that affect ecosystems and the role that topography, specifically mountains, might play influencing how ecosystems respond to these changes in climate. My main duties were to assist in performing several geochemical analyses on clay samples from John Day. X-ray fluorescence, X-ray diffraction, and delta-18 oxygen isotope analyses were the main tests we ran on the samples. These analyses helped us to reconstruct the paleoclimate and ecosystem of the John Day region while understanding factors that led to the transition from an ecosystem of 50 million years ago to the one we see today.

I joined this research group with very little background in paleoclimatology but with the help of my very supportive mentor, I was able to catch on quickly. I became familiar with concepts of paleoclimates such as chemical index of weathering rates, and delta 18 values from clay samples which can provide us with precipitation information. I was very excited to learn how to operate an X-ray diffraction and X-ray fluorescence machine. The coolest part was being able to help with performing geochemical analysis with a mass spectrometer capable of testing for delta 16, 17, and 18 oxygen isotope values. I gained a lot of valuable laboratory skills that are going to be very beneficial to me in graduate school research.

Aside from gaining research skills, there were a lot of opportunities for professional development through the weekly faculty seminars at which current research projects being carried out in Stanford School of Earth and Environmental Sciences were shared. There were also sessions on graduate school preparation including weekly GRE classes and graduate school information sessions organized specifically for SURGE students. At the end of the program, we had a research symposium for all SURGE students to present their individual research projects to Stanford Earth Science Department. This was also a great opportunity for professional development and enhancement of public speaking skills. The most fun parts of the summer program were the life-long friendships I have made, and amazing field trips organized for us. We went kayaking at the Elkhorn Slough on Monterey Bay, and many other tour sites. It was fun to explore San Francisco also during the downtimes of our rigorous schedule.

The Office of Multicultural Affairs in charge of the SURGE program made us all feel very welcomed and comfortable at Stanford to the extent that I had to constantly remind myself I was not a full-time student yet. And I must apply for admission be one permanently. Stanford had begun to feel like a second home to me in these short 8 weeks.

In conclusion, I will like to encourage all undergraduates out there to apply for REUs! The experience you will gain is invaluable! SURGE totally changed my perspective about life for the better. Overall, I was encouraged to follow my dreams, even the most ambitious ones, no matter what my circumstances look like. Everything is possible! If you would like to participate in SURGE 2020, be on the lookout; applications start on November 30, 2019! All the best!

A big shout out to our wonderful SURGE director, Dr. Lupe Carrillo, and my very supportive and best research mentor, Tyler Kukla!

About the Author

I am Shirley Tsotsoo Mensah, an international student from Ghana, who recently completed a bachelor’s degree in Geology at Eastern Illinois University. I am currently pursuing an accelerated master’s degree in Geographic Information Sciences after which I will continue to pursue petroleum geology at the graduate level.
Expanding Your Expertise Through Strategic Volunteering

My only bumper sticker is the classic red, white, and blue NASA emblem – a symbol ubiquitous in popular culture: on coffee mugs, T-shirts, sweaters, and jackets around the world. In many ways, I’m just another enamored space fanatic longing for rocket launch sightings and perhaps a journey to the Moon. But in other ways – through what I will here call “strategic volunteering” – I have had the privilege of fulfilling a childhood dream of actually working with NASA in some capacity.

For graduate students and undergrads, the chance to diversify our skillsets is traditionally restricted to taking new courses and perhaps taking on summer internship projects. For Ph.D. students, the only chance for diversification might come with a postdoc appointment in a slightly new field of study. Here, I hope to advocate for an additional avenue of experience-building: volunteering. Taking on a few hours of extra research each week can be an invaluable means to build out and expand your experience. For undergrads, it can build out your CV for grad school applications and build work experience. For grad students, it can gain you additional publications, as well as potential job leads and connections. Plus, the variety can be both enjoyable and intellectually stimulating! I’ve had the chance to travel to and present at three conferences in Houston, Texas and Paris, France just through volunteering.

I want to emphasize that volunteering can also break down some traditional barriers to entry into new fields. As long as you bring motivation, dedication, and energy to a potential volunteer experience, many potential advisors will likely welcome – to be frank – free labor to advance their own research interests. With zero experience in planetary science, I was able to land a volunteer research position with SETI/NASA. With absolutely no experience in policy, I landed a volunteer energy policy research position with a former Commissioner of the California Public Utilities Commission. I would venture to say that almost always, professors and researchers at any university have a large backlog of exciting projects that they would welcome an extra hand in tackling.

With regard to how to land positions, I would say this: don’t be afraid. Your motivation and an analytical mindset make you more qualified than you think. Learn to welcome the cold email: reach out to professors and researchers whose work fascinates you, and grab coffee with them. Explain that you would love to get involved, and that you are happy to work for free. If they have the bandwidth to do some supervising of your work, they will likely be keen to have your help.

So get out there and expand your expertise! I’ll close with some of the chief benefits of strategic volunteering:

1. Expand your expertise into fields and subjects you otherwise wouldn’t have had access to
2. Build close relationships with mentors in fields outside of your expertise
3. Gain additional research experience (valuable both for grad school applications, and for grad students to gain additional publications)
4. Open up new opportunities for yourself

About the Author

Zachary Burton is a fifth-year geology Ph.D. candidate at Stanford University. He studies the marine geology and natural resources of continental margins, as well as terrestrial analogues for martian sediments and materials.
We all go through change, it is a necessary and integral part of our lives. People encounter change as students, in our professional careers, and in our personal lives. This year has resulted in several changes for me, and I’ve been reflecting on what those differences mean for my daily life and for the future.

This summer, on the anniversary of the Apollo 11 mission, I found myself thinking about NASA and space missions. Going to our moon was an amazing accomplishment, and the possibility of going to another planet in the future is very exciting. How much have we learned about the formation of the Earth and our moon? What has this taught us about the formation of terrestrial planets and geology? The United States sent astronauts to the moon only 50 years ago. While five decades can seem like a long time, it is a relatively short period. Technology, society, and scientific discovery have improved significantly since the 1960s, and the discoveries made by NASA have helped to drive scientific discovery for all mankind. The University of Texas at San Antonio (UTSA), where I work and attend graduate school, also had its 50-year anniversary this year. As we learned more of UTSA’s history during new employee orientation, I considered the university’s history, and how much the campus and its programs, buildings, and students have grown over the years. It must have been very different to be a student when the geology program began in 1976!

This summer I was more retrospective than usual because I underwent several changes in my personal and professional life. I resigned from my job of over a decade, was unemployed for about six weeks, and just started a new position while continuing my graduate degree. I often think of my life -- academically, professionally, and personally -- as if I was traveling down a road. Sometimes the road is smooth, and I travel past milestones with ease. At other times, the road is more difficult. This past month has felt “uphill” as I learned a new job and started working on my graduate research proposal. I’ve had to remind myself not to think of the entire journey at once, as it can be rather overwhelming. I have been working on thinking of one goal at a time, and to try and balance my work, school, and personal life.

Back in June, I chose to resign from my job of 11 years, because I was ready for a change and wanted to focus more on school. I had worked at the same employer for 13 years. I knew my job and coworkers well and leaving was not an easy decision. I spent a month and a half unemployed, spending time at home, working on my summer independent study course, and searching for a job. Taking a break was the right choice for me at the time. The previous six months at work had been extremely busy, with more than the typical amount of overtime, and many large projects with challenging deadlines. I enjoyed having a bit of time to myself to relax, think about my academic and professional goals, and to give my brain and body a bit of a break.

While job hunting, I looked for both geology and administrative jobs, and settled on a full-time job at the UTSA. My job search was limited to the San Antonio area, as that is where I go to school and live, and relocating is not a good option at this time. There are often several open geoscience positions in San Antonio, and I applied for all that I was qualified for. I have work experience, but...
Peter H. Dohms, CPG-7141

WELL, that’s a silly title for an article in TPG! Here you are in school, months or a couple of years before graduation, and you have more important things on your mind than retirement (like that upcoming Petrology exam). Take it from me; I was exactly where you are now and I didn’t give even one minute of thought to retirement while I was in college.

By some stroke of good fortune, or hard work, or being in the right place at the right time (or all three, most likely) I was able to end my career and enter retirement in a generally good place, financially speaking (and a great place, geologically speaking). The purposes of this article are to (a) tell you how I did it, (b) tell you about some of the dead ends I avoided, and (c) provide a primer on various methods of financing your own retirement.

Oh - by the way, this article is not legal or investment advice, and does not express the opinion of AIPG on retirement planning. Neither the author nor AIPG is qualified to provide legal or investment advice. Legal advice should come from a properly-qualified attorney, and investment advice should come from a properly-qualified investment counselor or broker. There! (AIPG made me say that to keep us out of trouble).

It is important to recognize that most of us didn’t get into practicing geology for the money. In fact, I know of only two hard-rock geologists in United States history who became very wealthy. The first was Spencer Penrose, who made a small fortune in gold at Cripple Creek, then leveraged it into a huge fortune by bankrolling Daniel Jackling in the opening of Utah Copper (the Bingham Canyon mine). The other, described as the “greatest ore-finder in history,” is still alive, so I won’t mention his name (his field vehicle used to have “The Man” printed on its exterior).

First the primer. Here are several types of retirement planning vehicles:

**Social Security** is the term used for the Old-Age, Survivors, and Disability Insurance (OASDI) program in the United States, run by the Social Security Administration (SSA), which is a federal agency. While best known for retirement benefits, it also provides disability income and survivor benefits. Generally, the great majority of employees in the United States fall under Social Security; their income is taxed to support the program and their employer pays a tax equal to that deducted from the employee. Financial gurus are fond of warning younger people that “Social Security won’t be there in 2060” when people your age retire (though it’s very unlikely that Congress would not “save” it). It is regardless prudent to select one or more additional retirement vehicles.

**A pension plan** is a retirement plan that requires an employer to make contributions into a pool of funds set aside for a worker’s future benefit. The pool of funds is invested on the employee’s behalf, and the earnings on the investments generate income to the worker upon retirement. In the past 50 years, pension plans have generally fallen out of favor among employers owing, in great part, to more stringent Federal funding requirements. If your employer uses a pension plan, study the “fine print” carefully, especially if you’re offered an “early retirement” package.

An Individual Retirement Account (IRA) is an investment account designed for building retirement savings. There are several types — traditional IRAs, Roth IRAs, SEP IRAs, SIMPLE IRAs and more — and all offer tax benefits that reward you for saving. Here are the two most common types of an IRA:

- A traditional IRA is a way to save for retirement that gives you tax advantages. Contributions you make to a traditional IRA may be fully or partially deductible from current income, depending on your circumstances. Generally, amounts in your traditional IRA (including earnings and gains) are not taxed until distributed. You set this up yourself, or with a financial advisor; your employer has nothing to do with it.

- A Roth IRA is a retirement account that encourages you to save by also offering you a tax benefit. Unlike with a traditional IRA, your current year contributions to a Roth IRA are not tax-deductible. But those contributions and your investment earnings grow tax-free, meaning there’s no tax on your Roth IRA withdrawals in retirement. Again, your employer is not involved.

A 401(k) is a retirement savings plan sponsored by an employer. It lets workers save and invest a piece of their paycheck before taxes are taken out. Taxes aren’t paid until the money is withdrawn from the account. The big advantage of a 401(k) over an IRA is that the employer typically “matches” your contribution, dollar for dollar, up to a specified limit (i.e., “free” money). When you retire, your 401(k) account typically is rolled into your IRA.

Financial gurus are fond of warning younger people that "Social Security won’t be there in 2060" when people your age retire (though it's very unlikely that Congress would not "save" it). It is regardless prudent to select one or more additional retirement vehicles.

"
A 403(b) plan, also known as a tax-sheltered annuity (TSA) plan, is a retirement plan for certain employees of public schools, employees of certain tax-exempt organizations [501(c)(3)], and certain ministers. Individual accounts in a 403(b) plan can be any of several types. Money is deducted from a paycheck before taxes are taken out, and like the 401(k) taxes are not paid until money is withdrawn. The employer may or may not offer a matching contribution. Only geologists with unusual employment circumstances might qualify for a 403(b).

An employee stock ownership plan (ESOP) is an employee benefit plan that gives workers ownership interest in their company. ESOPs give the sponsoring company, the selling shareholder (in the case of a closely-held firm [read, “consultant”]), and participants various tax benefits, making them qualified plans. Employees pay no tax on stock allocated to time they are taxed on the distributions. As with other tax-sheltered annuity (TSA) plan, employees can be set up as for retirement purposes. A Keogh plan is a tax-deferred pension plan available to self-employed individuals or unincorporated businesses for retirement purposes. A Keogh plan can be set up as either a defined-benefit or defined-contribution plan, although most plans are set as defined contribution. Contributions are generally tax deductible up to a certain percentage of annual income, with applicable absolute limits in U.S. dollar terms, which the Internal Revenue Service (IRS) can change from year to year. Keogh distributions after retirement are taxable.

Fortunately, there’s no quiz on this article at the end of this issue of TPG.

OK, how did I do it? Thumbnail autobiography. I graduated from Michigan Tech in 1967 with a Bachelor of Science in Geological Engineering and two weeks later I joined The New Jersey Zinc Company in Tucson, Arizona to work doing mineral exploration. In the next 16 years, our exploration program evolved through several mineral deposit types (copper, to silver, some base metals, industrial minerals, and eventually to gold). I had the good fortune to be the first on the ground at a gold prospect in the Mother Lode, and relocated to the project site in 1980. Three years later, the project was sold (and was mined shortly thereafter), and I co-founded a small consulting firm with two partners.

We initially offered consulting services to the mineral exploration industry, but in a couple of years there was one of the periodic mineral exploration downturns and “consultants” were the first budget item to be cut. We were fortunately able to transition into “environmental consulting” (a new and rapidly-growing field) and our little company continued to grow.

In 1988, my family and I relocated to northwest Florida where I opened a branch office. Ten years later, the company and I parted ways, realizing that we’d grown apart. After a few months of running my own company, I joined a regional geoenvironmental consulting firm that wanted a Gulf Coast office, and my staff grew apace. After another ten years, our regional firm was bought by a national consulting firm. There I stayed until retirement in 2011. At the end of my career, I was specializing in solid waste issues and Superfund sites.

Over the course of that 44 year career, there were a number of changes. The big change in Social Security is that the withholding increased from 3.9% in 1967 to 6.2% currently, with that percentage paid by both the employer and the employee (totaling 12.4% of all wages).

When I joined NJZ in Tucson, the Company had a pension plan, of which I knew nothing. I believe that when my employment with them ended in 1983, somebody told me that (having passed the “magic” 15-year mark) I was “vested.” I gave it no more thought until my 60th birthday when a letter arrived asking if I wanted to start receiving my pension. Well, YEAH! So every month, the successor firm deposits an amount equal to about 54% of my 1967 salary into my checking account. No adjustment for inflation but it will last as long as I do. Currently, it’s about 5% of our monthly income.

The IRA was invented in 1975. I wish I had been paying attention at the time, so I missed out on taking advantage of 10 years of stock market growth (OK; here’s the most important “tip” for you — the more years you build your retirement account, the bigger it will be — start early and contribute until it hurts). My wife and I each opened an IRA in 1985 and we still have them.

The 401(k) was created by Congress (rumor has it, mostly by accident) in 1978. At the time I was still with NJZ and its pension plan, so I couldn’t take advantage. Our small consulting firm adopted a 401(k) plan after 1985 and when we parted ways in 1998 it had grown to a tidy sum, which I rolled into my IRA. I kept contributing to a 401(k) with the regional and national consulting firms, and upon retirement I rolled those sums into the IRA as well.

Congress established the Roth IRA in 1997, and again I made the mistake of not taking immediate advantage. In 2008, our financial advisor recommended that we each establish a Roth and we did so, but as Roth contributions must be made from “earned” (taxed) income, we had a very limited window of opportunity before the 2011 retirement.

The ESOP became popular after 1974, but costs of administration and record-keeping prevent many employers from taking advantage of the benefits (the greatest benefit for a privately-owned firm is receiving cash from the employee now, to be repaid when the employee sells the stock back upon
ADVICE TO STUDENTS


It is not always possible to open a Roth IRA.

A financial advisor can tell you if it's possible to open a Traditional IRA while you're working for the government; it should also be possible to open a Roth IRA.

In the course of my career, I was the co-founder or sole founder of five "closely-held" corporations. Being the founder of a corporation comes with stock in the firm. If the company is successful, and is eventually sold, the stock is purchased by the buyer. Four of the firms I was with had success and I was able to sell my stock. None of the sums was large, but together they made a difference.

So, what kind of a career path was helpful to me?

The 16 years working for an "old line" mining company with a pension plan has yielded a monthly sum of just over half of my starting salary in 1967. Like I said, pension plans have fallen out of favor, so the chances of your taking that route are very small.

Having a Traditional IRA was very good, for two reasons. First off, it got me in the habit of saving for retirement. Secondly, it provided a place for 401(k) funds to be rolled into on the three occasions when I changed employers. I just wish I hadn't waited 10 years to open one.

The 401(k) investments that I made, which were matched by the employers, was a very good way to go. The "company match" is like finding money in the street. Yes, I’m paying tax on the distributions from these investments, but it’s at a lower tax rate.

Being a co-founder or a founder of a privately-owned company is a big risk; it’s not for everyone. My experience was good, but if things had been different, it could have been terrible. A full discussion of advantages and disadvantages of such a step is well outside the scope of this article.

Finally, a word about other career paths.

Geologists employed by state or local governments are typically covered by pension plans that are sponsored by the government. Questions need to be asked of a government employer to determine whether the plan is adequately funded, how the benefits are calculated, how long your employment has to last for vesting to occur, and similar. Your financial advisor can tell you if it’s possible to open a Traditional IRA while you’re working for the government; it should also be possible to open a Roth IRA.

Academia also offers the potential for good financial reward. My younger brother earned his Ph.D. and became a world-class research academic. When he retired in the same year that I did, his retirement account was 50% larger than mine. But not every Ph.D. becomes a world-class researcher and tenured professor.

Here are some concluding recommendations:

- Don’t count on Social Security as your only financial asset in retirement; as soon as you enter employment, evaluate your best savings option, and start saving for your retirement. Do this even if it means spreading out repayments of other debt, or living in a less desirable abode;
- Engaging a financial counselor early in your career will pay dividends – select one very carefully (we use one of the major, old-line investment firms – choosing a crook could cost you everything);
- If your employer offers a 401(k) plan with an employer “match” of your contribution, your contribution should be not less than the maximum amount your employer will contribute, and, indeed you should invest the maximum allowable by law (if affordable);
- When and if you are invited to invest in an Employee Stock Option Plan, be sure and do so (unless you’re certain that you will be leaving that place of employment shortly);
- I can safely predict that new retirement planning options will be invented in the next 40 years prior to your retirement – pay careful attention to these developments and seek professional advice whether it’s good for your situation;
- Purchasing Powerball tickets is not good retirement planning; and, finally,
- Regardless of what retirement options open themselves up to you, be sure to take FULL advantage of each one – start early and save until it hurts.

Good luck in your career, and good luck building for your retirement.

About the Author

Pete Dohms is a retired geologist living in Payson, Arizona, following a 44 year career that had not one day of unemployment. He is a frequent contributor to TPG.

Nevada continued from p. 12


About the Author

Dan Zampirro has lived in Carson City for the past 15 years with his wife, children and grandchildren. A graduate of Mackay School of Mines, Dan started his career with exploration for Felmont Oil Corporation and later Homestake Mining Company before 14 years in mining at Round Mountain Gold and 4 years at the Clayton Valley mine. He is currently employed in the Nevada State Engineers office, Division of Water Resources.

Foundation of AIPG

William J. Siok Graduate Scholarship Program

2020 Scholarship Essay Topic

Focus on a single theme of your choice, and explain how the profession of geology, over the coming decade, could best contribute to addressing a problem for the well-being of the public. In your essay explain (1) Why your theme choice is significant and (2) How professionals educated in geology are essential to contributing successfully to addressing the problem. Try to be as specific as possible in addressing Item #2.

For complete instructions on how to apply, go to https://aipg.org and click on membership then the students category.

Application Deadline

Applications must be received by midnight Mountain Standard Time (MST) on April 1st, which is to say, before on February 1st.

Scholarship is awarded the month of May.
Introduction

During October 2019 AIPG asked its members to select one of ten statements that summarized a view about climate change. The range of statements varied from climate alarmist through those denying that humans have any effect on climate change to those with no opinion at all. Those summarizing statements were:

A. If drastic worldwide measures are not begun immediately to combat climate change, civilization as we know it will end in 10 to 12 years.

B. Climate change caused by human activity is a serious threat requiring significant corrective action in the near term.

C. Corrective actions to combat climate change caused by human activity should be intensified above the present.

D. Human activity is causing measurable changes in climate; corrective action may be needed.

E. I agree that human activity can have some effects on climate; quantification of such effects requires further study.

F. The science of climate change is not settled; I cannot judge whether it’s occurring.

G. I am not convinced that human activity can cause planet-wide climate change.

H. If climate change is occurring, it is due to naturally occurring fluctuations.

I. I have not conducted enough personal research into the topic to have an opinion.

J. I am too busy to learn about this entirely theoretical subject.

In addition, respondents were asked to supply AIPG membership category, age range, area of main geoscience specialty, and main employer type. This article presents the results from the questionnaire.

In addition to the summarizing statements and demographic data, 49 comments were received. One comment was, “I appreciate AIPG for polling its members on this important topic.” Another opined, “Well worded questions covering gamut of stances/opinions.” Yet another commented on the character of the summarizing statements observing that, “essentially your survey is one question and multiple answers are possible.” Agreed. When Peter Dohms, CPG-7141, John Berry, CPG-4032, and I were drafting the summarizing statements, we wanted a series of statements ranging from the fervent alarmist to the ardent denier positions. Other comments addressed aspects of specific positions on the subject that will be discussed later.

Questionnaire results

Table 1 presents the number of respondents by membership category along with the total AIPG membership data as of October 1, 2019.

<table>
<thead>
<tr>
<th>Membership Category</th>
<th>Questionnaire</th>
<th>AIPG Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPG Active</td>
<td>456</td>
<td>2,702</td>
</tr>
<tr>
<td>CPG Retired</td>
<td>126</td>
<td>526</td>
</tr>
<tr>
<td>Member Active</td>
<td>118</td>
<td>798</td>
</tr>
<tr>
<td>Member Retired</td>
<td>21</td>
<td>37</td>
</tr>
<tr>
<td>Student, All</td>
<td>66</td>
<td>2,028</td>
</tr>
<tr>
<td>Young Professional</td>
<td>20</td>
<td>252</td>
</tr>
<tr>
<td>Student BS</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Student MS</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Student PhD</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Total Complete</td>
<td>807</td>
<td>6,343</td>
</tr>
</tbody>
</table>

A total of 807 complete responses were received representing a 13% overall return. CPGs, both active and retired, responded in greater numbers than their overall percentage of membership while Students constituted 8% of the responses compared with 32% of overall membership.

Figure 1 on page 30 presents the number of responses to each of the 10 summarizing statements. Statement J, “I am too busy to learn about this entirely theoretical subject,” received no responses and will receive no further consideration.

There are clearly two or three groups of summarizing statements. The 3-statement grouping would be ABC, DEF, and GHI. The 2-statement grouping has an ABCDE group and a FGHI group. The problem is the middle summarizing statement E, with 165 responses, the second highest total and 20% of the total responses. Statement E agrees that “human activity can have some effects on climate; quantification of such effects requires further study” thus supporting its inclusion into the ABCDE group. Statement F, “The science of climate change
is not settled; I cannot judge whether it’s occurring” is more closely aligned with the FGHI group than it is with statement E. These two groupings, ABCDE and FGHI will be used in this analysis. Summarizing statements for these two groupings are:

ABCDE: Some of the observed climate change is caused by human activity, the burning of fossil fuels to increase the CO₂ content of the atmosphere in particular. The precise quantification and prediction of these impacts is still being resolved.

FGHI: If climate change is occurring, it is entirely due to naturally occurring fluctuations.

Figure 2 presents the responses to the summarizing statements by geoscience specialty area. The Other specialty area in Figure 2 consists of those respondents whose answer to the geoscience specialty question was something other than the given choices. The responses varied widely, for example: all of the above, cryosphere, geophysics, geomorphology, glacial, more than one of the above, paleontology, structure, sedimentation, valuation, water resources, etc. This simply reflects the variety of specialties in AIPG’s membership directory. There are times, like this, when you would like a “choose the best fit” answer. But that would demand an “other” category.

Overall, the ABCDE summarizing statement grouping is greatly preferred. However, 41% of the mining (plus coal and uranium) respondents are not convinced that humans have anything to do with climate change. Surprisingly, 61% of the oil and gas respondents favored the ABCDE grouping.

Table 2 presents the percentages of mining (plus coal and uranium) and oil and gas specialists who responded to the 9 summarizing statements. Statements E and H received the most responses and highest percentage from both groups.

![Figure 1 - Number of responses to the summarizing statements.](image1.png)

**Figure 1**

![Figure 2 - Number of responses to summarizing statement by geoscience specialty.](image2.png)

**Figure 2**

Comments on the Questionnaire

As noted in the Introduction, 49 comments were received as part of the responses to the questionnaire. Most of the comments expressed opinions either in favor of human-caused climate change impacts or totally dismissed the concept. For example:

“I am frankly distressed that a significant portion of the AIPG membership still refuses to accept the reality of the acceleration of climate change by human activity. How much more data do they need??” This comment came with a preference of summary statement B, climate change caused by human activity is a serious threat requiring significant corrective action in the near term.

“I believe world-wide changes are required immediately or less aggressively within the next 10 years on the outside relative to carbon emissions control and the climate. Even significant scale changes will not invoke immediate response. We will likely well require decades to attempt to slow or reverse the current climatic trends that have been scientifically demonstrated.”

This comment came with a preference of summary statement B, climate change caused by human activity is a serious threat requiring significant corrective action in the near term.

“Climate change is occurring, the likely causes are many (natural and with some human contribution); however, there are many different opinions among individuals that have the qualifications to render an opinion.” This comment came with a preference of summary statement E, I agree that human activity can have some effects on climate; quantification of such effects requires further study.

“This should not be ‘an opinion’ by AIPG. The vast amount of research on this subject clearly indicates global warming and climate change caused by the overuse of fossil fuels is a serious threat to our planet. As scientists we should responsibly meet this crisis and support the changes necessary to adequately address this issue.”

This comment came with a preference of summary statement B, climate change caused by human activity is a serious threat requiring significant corrective action in the near term.

“Climate change has happened since the beginning of time from cyclical natural causes. Most of the rhetoric on climate change is being conducted by agenda driven politicians with very little if any formal training in geosciences. Man’s effect on climate change is not proven and would be very difficult to quantify.”

This comment came with a preference of summary statement H, if climate change is occurring, it is due to naturally-occurring fluctuations.

“Anthropogenic climate change is a political hoax to redistribute wealth and encourage socialism.” This comment came with a preference of summary statement G, I am not convinced that human activity can cause planet-wide climate change.

“For the final comment, “I appreciate AIPG for polling its members on this important topic. I feel that the AIPG needs to support the consensus that action needs to taken to address the threat of climate change on our environment.”

Conclusions

The responses to AIPG’s climate change questionnaire were grouped into two summarizing statement groupings, ABCDE and FGHI (Figure 1). Summarizing statements for these two groupings are:

ABCDE: Some of the observed climate change is caused by human activity, the burning of fossil fuels to increase the CO2 content of the atmosphere in particular. The precise quanti-
Why Should Geologists BeLicensed?
An ASBOG Perspective

Erick Weiland, CPG-6892, P.G.¹ and Jason Patton, PhD, P.G.¹

Should geologists have to be licensed to practice? As is true so many times in life, this seemingly simple question is difficult to answer with a few short words. This article will lay out the reasons why licensure of certain geologists is important by first describing what licensure is and is not, and then describing the kinds of situations where licensure is both required and critical.

We will start by describing, in general terms, the purpose for requiring a license in any professional discipline that affects the public. Although it takes different forms for different areas and disciplines, the primary purpose of all licensure is to protect the health, safety, and/or welfare of the public. A critical part of this protection comes from the fact that a license can be revoked by the government for negligence or malpractice, thereby not allowing that person to continue to practice.

Although it takes different forms for different areas and disciplines, the primary purpose of all licensure is to protect the health, safety, and/or welfare of the public. A critical part of this protection comes from the fact that a license can be revoked by the government for negligence or malpractice, thereby not allowing that person to continue to practice. For example, a medical doctor has a license because the practice of medicine directly affects the health, safety, and/or welfare of the public. A civil engineer also has a license because the practice of civil engineering directly affects the public. If a medical doctor or civil engineer is negligent in their duties, their license can be revoked and they will no longer be allowed to practice. This implied threat to the livelihood of a doctor or engineer forces them to stay current in their field, make better ethical choices, and report the negligence of others thereby protecting the interest of the public. Furthermore, when making a determination about someone’s qualifications for licensure, it isn’t about your resume or who you know. It is about measurable criteria (education, experience, exams), defined in law and regulation, applied fairly, applied consistently, and subject to an appeal process heard before a judge in court.

How does this relate to geology? The discipline of geology has come to be demonstrably large and ever-growing. Within this large community, a segment of geological practice directly affects the health, safety and welfare of the public, including the environment and the feasibility of engineered/constructed works. These geoscientists use their special knowledge and expert experience for the benefit of the public through the creation or analysis of things such as:

- water projects (e.g. groundwater supply/declines, water recharge/storage, pipelines, and canals),
- geological hazards (e.g. faults and fissures, landslides, volcanic activity, foundation stability for buildings, dams, bridges and roadways, swelling soils, and karst systems),
- environmental liability (e.g. groundwater quality, spring flows, contaminated soil, injection wells),
- financial and public documents (e.g. economic resource estimates in mining and oil/gas),
- public and private construction design (e.g. highway, dams, bridges, sub-divisions, subsidence issues), and,
- many other areas of professional geological work.

All of these, and others, have the potential to directly or indirectly affect the health, safety, and welfare of the public if not properly recognized and/or analyzed by qualified geoscientists. Few other professions affect the public more than geology, especially when working in collaboration with the environmental, construction and engineering professions.

One argument used against licensure is that the certification of geologists through national professional organizations is sufficient to protect the public. On the surface this looks to be a reasonable argument, but closer inspection makes it apparent as to why certification cannot replace licensure. So what’s the difference? Simply put, as mentioned previously, a license is the government’s permission for you to do something (e.g. drive a car) that can be revoked due to negligence or malpractice. A certificate is the comparison of something to an established standard (e.g. a college diploma) and can be granted by a non-governmental authority. A certificate from a professional organization (e.g. American Institute for Professional Geologists) can be a great way to show the world you have expertise that meets a certain standard, but it is not revocable by governmental authorities. Holding a license to practice geology means being subject to legally enforceable consequences for negligence, incompetence or other violations. These consequences include fines, probationary conditions, and/or
revocation of the license. Additionally, instead of voluntary codes of ethics applied through professional organizations, licensed geoscientists must adhere to professional standards and codes of conduct that are clearly defined in the rules and regulations of each state and are legally enforceable.

At this time, thirty-one (31) states and the territory of Puerto Rico have deemed that the protection of the public by licensing geologists is essential. Because geologic licensure is controlled by the states, various exemptions to the general overview discussed here exist. For example, in most states, a college professor working on a groundwater quality project that is for research purposes only would not have to be licensed to perform the research project. That same college professor, if paid by an engineering firm to develop an aquifer potential yield report may need to be licensed by, or working under a licensee in, the state in which the work was performed. Exemptions to licensure do exist and interested geologists should contact their state geological licensing board to see what is considered “geologic practice” in their state.

Finally, according to American Geosciences Institute’s (AGI) recent report on hiring trends (Geoscience Currents No. 135), more than 40% of all bachelor’s graduates were going into either the areas of environmental services, engineering/construction, or federal government – all areas where licensure is either required or strongly encouraged. Based on the above discussion, it is our belief that more universities and professors should encourage their students to start their pathway toward licensure and take the National Association of State Boards of Geology (ASBOG) Fundamentals exam upon graduation, thus starting their professional careers. In engineering schools, engineers are encouraged to initiate the licensure process prior to graduating with an engineering degree and the majority of their professors are licensed. Unfortunately, this is not the case for geologists. To date, only a handful of geology programs have encouraged students to start on this path that more than 40% of their graduates will be required to finish.

“Civilization exists by geological consent, subject to change without notice,” is a popular saying by William Durant with much merit and Ralph Waldo Emerson said: “We learn geology the morning after the earthquake, on ghastly diagrams of cloven mountains, upheaved plains, and the dry bed of the sea.” When dealing with matters that directly affect the well-being of the public, only licensed geologists should determine the level of geological consent and avert, or at least minimize, the aftershock of a geologic event. Professional licensing has always been a reflection of what is happening within the regulated professions. The future of licensing is about understanding that being a licensed professional isn’t only about technical competence. It is about protecting your neighbors, your family, and your friends.

About the Authors

Erick Weiland is the Past President of ASBOG, having served as President in 2018. Jason Patton, PhD, is the current Treasurer of ASBOG and will be ASBOG’s President Elect in 2020.

1. c/o National Association of State Boards of Geology (ASBOG), P.O. Box 5219 Douglassville, GA 30154

The Realities of Pace and Compass Traverses

The first afternoon of my undergraduate geology course involved the determining one’s pace so that one could do pace and compass traverses. This was in the days long before GPS systems became readily available. Pace and compass was the “best” although imprecise means of determining your position during a traverse. I had just spent two years as a field tech for a mining exploration firm and had many line miles of pace and compass work under my belt. I went along with the rest of the class to the intramural football fields so that we could measure our pace over known hundred-yard distances. I happened to be wearing a pair of cowboy boots that afternoon. The professor leading the exercise asked if I always wore these cowboy boots in the field. I replied that I sometimes wore them, but other boots at other times. The professor said that it was very important to always wear the same pair of boots in the field because heel height affected one’s pace. It was clear to me that the professor, who I had not previously known, had never done any pace and compass traverses over wooded hills, a fact confirmed when no mention was made of the secant table, which provides the number of feet that must be added to slope distance to go a particular horizontal distance, say the 600-foot length of the end line of a lode mining claim. Because it was the first class of the term, I decided not to mention his clear ignorance of the niceties of pace and compass traversing.
Dear Geologists-to-Be:

It's hard to avoid these few sentences sounding like uninvented pings from a scraggly oldie who holstered the rock hammer decades ago. But my Brunton still points north (and I know my local declination), so yes I have some directional words. Should you decide to discard them, figure out why.

When I launched into geology (as a formal student, that would be in 1971), one of the exciting expectations was that this career would lead in many directions and to many interesting realms. That turned out to be true, but not in predictable ways. Reasonably expectable locations included several in the western half of the U.S., though some were more southerly than anticipated.

Less expectable ones included western and southern Africa, South America, Chicago, and Boston. Professional focus started out in hydrocarbon exploration, but grew to envelop groundwater extraction for mines, soil remediation, probabilistic mapping of UXO1 (UneXploded Ordnance) distribution, and CCS. The last decade's work – while still relying on earth-science expertise – has been labeled Risk Management. Career changes were brought about by external conditions as well as opportunistic choices ... and almost never by planned progression! So the first of two take-home messages is: Expect change, Expand your skills, and Plan to be nimble.

That's the lesson from stratigraphic history up until this instant of the Anthropocene. You might build models and simulations in order to see forward, but the handwriting on the wall should do. What's looming for geoscience? Same as for everyone else; only more so: Climate change. Global warming. Sea level rise. Resource extraction, resource prices and demand, water availability especially, soil science for agriculture, erosion and sedimentation in the wake of wildfires, risk-based triage of societal choices involving ghg emissions and geoenengineering ... what aspects of earth science will not be affected? If you noticed "CCS" in the "professional focus" list above, know that some working earth scientists (even outside of academia) added "AGW" to their vocabularies 15 or 20 years ago; this is not news. So the second of two messages is: Envision your professional response to climate change, and act on it.

There will be plenty of work to be done; best of luck.

Ken Hnottavange-Telleen, CPG-10445
GHG Underground LLC
Brunswick, Maine

So the first of two take-home messages is: Expect change, Expand your skills, and Plan to be nimble.

Continued from p. 15

Unfortunately it is not in geology. While I have many "soft skills" that would likely translate, I determined that I would need to gain experience in a geoscience position to meet the requirements of many employers. I also noticed that many positions preferred or required a master's degree, so that reinforced my goal to earn a M.S. in geology. In the future I may also investigate internships in order to gain experience. For now, I'm going to continue working full-time while attending school, as I have done for the past several years.

I started my new position at UTSA in September right after the start of the Fall 2019 semester. Most days are busy with lots to learn, and I enjoy working there! I have a regular schedule that works with my classes, and my coworkers are all great people. There is also a convenience aspect to working at the university -- I don't have to drive back and forth between work and school for classes, and if I need to chat with a professor or drop off paperwork, it's a quick walk to a nearby building. I have a better understanding of how UTSA supports its students and how the campus runs behind the scenes.

Continuing my graduate program in geology has been wonderful, though it is a lot of hard work at times, and occasionally a source of stress. While I've had to make sure I appropriately prioritize my time, I'm invested in earning my degree. This semester I have started working on the proposal for my thesis work. Trying to think about the entire project is a lot to consider, especially as I am still working with my professor to figure out the details and scope of the project. While this is a bit daunting, it is also exciting because it is the first step in working on my thesis!

Change can be difficult to process, and several changes over the past four months have occasionally felt like a lot! The first month of the Fall semester went by in a flurry of activity. I learned new skills, new processes, met several new colleagues, students, teachers, and gained knowledge from my graduate coursework. Reflecting on the past regarding both my own life often leads me to think of the future. How will my research fit into a larger understanding of geology? How can I contribute to scientific knowledge and discoveries? Finishing more of my graduate coursework and getting started on my thesis proposal are exciting steps in my academic career. I'm feeling more comfortable now, and things are settling into more of a routine. It is rewarding to work at the university I attend and feel more connected to the campus as both a staff member and a student.

About the Author
Heidi Harwick completed her B.S. in Geology in 2018 and is a graduate student at the University of Texas at San Antonio (UTSA), pursuing an M.S. in Geology and a graduate certificate in Geographic Information Science. She currently works as a Program Specialist at the UTSA College of Engineering Student Success Center, and previously worked at Educational Testing Service as a Proposal Production Specialist. Prior to moving to San Antonio in 2004, Heidi worked and lived in Southern California and served in the U.S. Marine Corps.
Questionnaire continued from p.21

...ification and prediction of these impacts is still being resolved.

FGHI: If climate change is occurring, it is entirely due to naturally occurring fluctuations.

The responses by age presented in Figure 4 are the best differentiator of the responding AIPG members view of the summary statements on climate change. AIPG’s younger members are far more in agreement with human-caused climate change than the Baby Boom-age members. If Student members had responded in numbers reflecting their percentage of AIPG’s total membership, the percentage of those supporting the ABC peak would be significantly higher.

Going forward; is it time for AIPG to issue a consensus statement on climate change? The majority of respondents recognize the human activity is affecting the climate, those agreeing with the ABCDE summarizing statement grouping, although by how much and how soon action must be taken require careful wording of a statement. However, significant minority of respondents (27%), those agreeing with summarizing statement grouping FGHJ, will not accept a statement that humans have anything to do with climate change. It is also worth remembering that the Student members generally did not respond to the questionnaire. Had they done so, the percentage in favor of the proposed consensus statement would be far higher. Students represent the future of AIPG. AIPG will be able to attract and retain younger members. Those members that favor summarizing statement grouping FGHJ can lend their voices and opinions to the debate that is now developing worldwide as to what actions, if any, make sense. In any case, opportunities abound for AIPG member geologists to address the many existing and potential future problems that the world faces.

Success through Authentic Adaptability

James L. Gooding, MEM-3070

Completing your college or university education is a significant milestone — but only the first step in becoming a productive professional. Joining the work force will both open a world of opportunities and test your survival skills. The crucial ingredient for your success will be your resolve to adapt to changes in an authentic manner — where you demonstrate value through being trustworthy, dependable and willing to take on and master new things.

Having spent 38+ years across multiple careers — both in government service and in private industry — I learned valuable lessons from working for many different organizations and supervisors. Here are some of my most important takeaways:

- Most of what you will eventually know will be learned after you finish school
- Lifelong learning will keep your skills sharp and your spirit strong — take it on as an adventure
- The geosciences are most useful when studied and applied in the broad sense — geology leads the way but you can grow faster and better by including ocean and atmosphere in your thinking
- A good boss will appreciate (and reward) your willingness to take on new responsibilities even if they might be outside the comfort zone defined by your school work
- Clients (both internal and external) will value your expert ability to explain science in simplified but substantive terms — but take care to respect their intelligence as they probably are experts on things other than geoscience

My schooling goes way back to the time that plate tectonics was becoming accepted as a legitimate theory. But I quickly became interested in interdisciplinary studies involving geology, geochemistry and climatology. I also had the great opportunity to participate in the geosciences growing into an essential part of comparative planetology. It all became woven together along pathways I had not anticipated. Now I assist industry clients in using geoscience to manage risks and make their businesses resilient to natural hazards.

Congratulations on choosing the geosciences as your profession. Now, be ready and eager to take on change with authentic adaptability as you become a working geoscientist.

About the Author

James L. Gooding is founder and Managing Director of Geoclime, LLC, providing quality and risk management consulting. After earning his Ph.D. in geology (University of New Mexico), he successfully completed multiple careers in government and industry before becoming a consultant.

Reminder!

Renew your membership dues before February 15, 2020.

You may pay online at aipg.org or mail in your form and payment to:
AIPG Headquarters
1333 W. 120th Ave., Suite 211
Westminster, Colorado 80234-2710
The Marvelous and Exotic Landscapes of Fjords

Aristotle once said, “In all things of nature, there is something of the marvelous.” Unknown to the great ancient philosopher, his quote has multiple modern connotations, from a beautiful piece of contemporary artwork to a fictional comic-book superhero. From the perspective of a planetary geologist, I interpret Aristotle’s statement in a similar manner to his probable original meaning: that the landscapes surrounding us, or pictures that capture the surface of distant worlds, incite an internal, awe-inspiring wonder. This thrill due to viewing the Earth’s scenery or that of another celestial body in the Solar System invokes the question: how was the landscape sculpted to today’s shape?

I constantly challenged myself with this question when I ventured amongst the gorgeous landscapes of Norway this past summer. More specifically, I traveled to the western coast of Norway to visit Hardangerfjord, the second longest fjord in the country and fourth longest in the world. The seven-hour ride on the train from the Norwegian capital of Oslo to the western coastal city of Bergen, located where the North Sea and Norwegian Sea meet, was filled with rolling green hills, waterfalls, villages, camping grounds and mountains. Upon finally arriving at Hardangerfjord, the landscape was truly a marvel to behold. How was this part of the northern European landmass carved into multiple fjords?

The Scandinavian Mountains and Appalachians

Approximately 400-450 million years ago, during the late Ordovician to early Devonian period, a dual mountain-building event occurred. An open area of seawater called the Iapetus Ocean had three ancient continents nearby: Laurentia, Baltica, and Avalonia. The northern portion of the Iapetus closed first when Laurentia and Baltica collided. This collision is called the Caledonian orogeny and it uplifted rock of what would become the Scandinavian Mountains that, today, make up portions of the northern European countries Norway, Sweden, and Finland. The southern and final portion of the Iapetus Ocean closed second as Avalonia crashed into the Laurentia landmass. This event was named the Acadian orogeny and it formed portions of uplifted landmass that are a part of the eastern United States terrain.

When comparing the eastern United States to the western Scandinavian landmass, there are noticeable similarities and differences for each that indicate unique erosional his-
tories. The Scandinavian Mountains and Appalachians are like twin babies separated at birth; they both have a similar foundational genetic makeup, but the environments they have been exposed to slowly evolved each into its own independent countryside. These mountainous regions have undergone much weathering and erosion from the time of the creation of the supercontinent Pangaea to that of its eventual breakup as the Atlantic Ocean opened. The main difference observed today between northern Europe and the eastern United States is the salient fjords of Norway’s coastline. This suggests that the geomorphological mechanisms that constructed the fjord landscape affected northern Europe, but not eastern North America.

**A Fjord is Born**

One of the geological events that can most drastically alter the shape of a landscape, and has been experienced in the relatively recent past, is an ice age. As glaciers move, a U-shaped valley forms in the surrounding bedrock as it is gouged by sharp rocks that are entrained in the non-melting ice.

In the beginning of the Tertiary period about 65 million years before the present, the gently rolling topography on either side of the Atlantic was uplifted to form the Scandinavian Mountains and the Appalachians. On the Norwegian side within the last million years, the land was covered by immense ice sheets (at least four times), which gashed out the previously shallow valleys to greater depths. On the United States side, however, the great ice sheets did not extend further south than the state of New York and were unable to carve deep valleys near the coastline. The deep valleys forming the Norwegian coastline were flooded by the rising oceans at the end of the ice age 12,000 years ago, thus creating the long, narrow inlets now known as fjords.

Other fjords do exist throughout the world such as the northwestern coastline of North America (e.g., Alaska, British Columbia), New Zealand, the southern coast of South America (e.g., Chile, Argentina), and northeastern Canada, to name a few examples. Fjord-like features can also form inland away from the continental coastlines from rivers exiting mountain fronts such as in Italy and Switzerland. Alternations of glacial ice formation during cold periods followed by glacier retreat and eventual sea level rise and valley flooding, to form a fjord, amid a warm stretch of time, is a part of Earth’s hydrologic cycle. On Earth, water exists on the planet’s surface as solid, liquid, and vapor, sustaining environments that permit geomorphological structures to be sculpted out of the bedrock. The comparative planetary scientist in me contemplates whether a planetary body, other than Earth, that maintains a volatile (like water) in all three physical states on its surface could also have fjord-like landscapes.

**Exotic Fjords**

We do know of one exotic world within the Solar System that undergoes a hydrologic-like process similar to Earth. Titan, a frigid outer moon of Saturn with surface temperatures around 91 K (-182°C), withstands a cycling of methane on its surface. Titan’s surface is cold enough for its crust to be composed of water ice and has an environment hovering near methane’s triple point (i.e. the temperature and atmospheric pressure at which a compound can exist in all three physical states on a planet’s surface). Methane on Titan has been observed in liquid river networks, hydrocarbon lakes, and as vaporous clouds in a nitrogen-rich atmosphere. A side-by-side comparison of satellite imagery of Titan and Earth’s surfaces suggests that the two planetary bodies have very comparable geomorphological processes.

Does Titan have fjords? Based on what we currently have observed and understand about Titan’s surface, the answer is probably not. First, solid methane has not been directly observed, but may exist (or have existed in the past) on Titan’s surface. This “glacial methane” would be required to carve out the underlying icy crust. However, we do not fully understand if solid methane can erode frozen water efficiently because it is difficult to replicate Titan’s surface environment in a laboratory setting on Earth to determine if solid methane’s density could dredge the water ice crust. Second, U-shaped valleys that glacial ice sculpts on Earth are not found on Titan’s surface. The fluvial dendritic patterns on Titan appear to have more elongated V-shaped valleys that imply a potentially slow erosion of the icy crust from liquid methane runoff. Weathering and hydrologic-like processes on Titan are mostly analogous to Earth, but because Titan’s surface volatiles are chemically different, more research is necessary to decipher the observations made of this alluring world.

Although future humans may space-travel to Titan and not observe any fjords, I would still classify Earth’s fjords as “exotic landscapes.” Hardangerfjord in western Norway took my breath away because it is unlike most scenery I have observed in my lifetime. A landscape that appears so unique to us raises questions about our geological understanding of Earth, and forces us to ponder the similarities and differences between other observed landscapes, posing more bewildering questions for humans to solve. Yet, as geologists and scientists, we love to puzzle the marvelous nature of the universe.

**About the Author**

Steven M. Battaglia is a science writer with educational roots at the University of Illinois and Northern Illinois University. Photos taken by Steven Battaglia in August 2019.
Designing a hands-on environmental sampling training course for students that meets the requirements of industry

Keith Torrence, Ph.D., CPG-11647

Birgit Hagedorn, Ph.D.

A large percentage of new geology graduates will find employment within the environmental sector and will likely be engaged with clients and regulatory agencies on permitting, environmental baseline studies, contaminated site assessment, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and on supporting engineering projects. Compared to the traditional mining and oil & gas sectors, demand for environmental professionals is generally less volatile, is often based in major population centres and offers a greater degree of career stability. The environmental profession encompasses a wide range of degrees, including chemistry, engineering, geology, hydrology, environmental law, and biology. This can make for a varied and stimulating career choice.

As undergraduate studies rarely provide an adequate foundation for defensible environmental sampling and data
collection, environmental consulting companies generally provide on the job training of new staff in the field. This can limit training to project-specific tasks, with quality assurance and control considerations dictating sampling methodology, but on-the-job training often fails to provide background knowledge of sampling media and understanding of why these methodologies and regulations are in place and important. Further, each individual state can mandate sampling protocols and analytical methods, which can be challenging for out of state crews. Mistakes in the field can be difficult and expensive to rectify.

The State of Alaska regulates water quality, contaminated sites, air quality, and spill response through the Department of Environmental Conservation (DEC). This agency publishes a Field Sampling Guide which provides fundamental guidelines, methods and equipment options for sample collection at sites under their jurisdiction. This guidance is supplemented by additional guidance documents and memoranda to address specific sampling issues and contaminants of concern. Much of this guidance is promulgated as regulations in 18 AAC 75 and 18 AAC 78. Of note is that these regulations specify the minimum qualifications for environmental samplers and for environmental professionals who prepare work plans, investigative and other reports. Analytical data from samples that have been collected by technicians who do not meet these qualifications may not be acceptable to DEC.

At one level the role of an environmental sampler is straightforward. Analytical laboratories provide the appropriate bottles, jars and coolers. Soil and water samples must be collected at the correct locations, preserved and shipped to the laboratory within the specified holding time. In practice, environmental samplers are the eyes on the ground and are often required to adapt quickly to actual situations. This requires a basic understanding of the pollutant (e.g. gasoline) to be sampled and of its interaction with water and soil.

In Alaska, most remediation projects are undertaken in remote locations where the logistics of deployment and transport add greatly to the complexity (and cost) of the project. Staffing these projects with local people, who have experience of the conditions and the necessary field craft, makes economic sense for the consultant and the community: most villages in Alaska have chronic unemployment. Therefore, training of local hires in robust environmental sampling methodology benefits all parties. To meet this objective, we have designed a training program in environmental sampling, drawing on our decades of field experience. A kick-off workshop was held in Utqiagvik (Barrow), Alaska in 2015, with support from Ilisagvik College and, Ukpikavik Iñupiat Corporation. The goal of this initial workshop was to help local residents gain seasonal employment on the numerous federal remediation projects in the region. Since this first workshop, the training has been further developed based on student feedback, state requirements, changing regulations and incorporation of topical issues, such as multi-incremental sampling and the specific requirements for sampling of polyfluorinated substances (e.g. PFAS). To date, over 50 students have participated in workshops. In 2016, the State of Alaska recognized this course as meeting the educational requirement to become a Qualified Environmental Sampler.

The core module of the workshop is the collection of soil and water samples using a methodology that would be acceptable to the Alaska Department of Environmental Conservation (ADEC) and following proper protocols to preserve and document sample collection using chain of custody forms. Other modules cover soil classification and screening methods, monitoring well design and measurements, groundwater sample collection, discharge measurements and overall contaminated site assessment. The latter was of great interest to many course participants given the high number of contaminated sites in rural Alaska.

A typical workshop program is shown on page 30.

A core focus of the workshop is to provide hands-on experience with sampling and monitoring equipment that is prevalent in the industry. For example, multi-parameter water meters were used in preference to laboratory-grade individual pH meters as in our experience these are more commonly used by professional consulting companies. In-state analytical laboratories that are primarily used for environmental projects provided sampling bottles and instructions on sampling as required for their laboratory analysis for hands-on sampling. Considerable emphasis is placed on the proper calibration of monitoring and screening instruments (e.g. pH, turbidity, photo-ionization (PID) for volatiles) and the documentation necessary to support field measurements. Field exercises of 2 to 4 hours provide

---

2. AAC -Alaska Admin Code; regulations promulgated by State Agencies.
Syllabus
Qualified Environmental Sampler

Day 1

Introduction to “Qualified Environmental Sampler” (classroom):
Conceptual site models, environmental media & contaminants, sampling plans, sampling strategies, safety protocols, general sample handling, quality control

Water Quality and sampling (classroom):
Water cycle, water in permafrost environments, water quality and contaminants, examples in Alaska, drinking water standards, water sampling strategies, field parameter, related instrumentation.

Field equipment (lab):
Introduction to field monitoring equipment, calibration procedure, storage, testing equipment and some standard analysis methods.

Day 2

Sample handling (classroom):
Handling of environmental samples, holding time, preservation, QC samples, packing of cooler, shipment, receiving and transport.

Water sampling exercise (lab).
Lab: Establishing a sampling plan, example University Lake, sampling location, sample IDs, calibration of equipment, sample container, sampling equipment list.
Field: Basic water quality measurement, sampling and preservation, discharge measurement, packing of cooler, chain of custody forms.

Q&A water sampling.
Discussion: Sample labelling, trip blanks, field blanks, field book, COC, temperature monitoring blank….

Day 3

Groundwater (classroom): Occurrence and sampling methods, different pump systems, contamination of groundwater by hydrocarbons (classroom).

Preparation for groundwater sampling (lab): Calibration of monitoring equipment, development of sampling plan, packing of sampling equipment.

Groundwater sampling (field), groundwater level, volume calculation, pump test, usage of flow-cell with YSI, Inc., equipment to determine stabilization of GW parameter.

Q&A: Groundwater sampling: Comparing groundwater and surface water samples, lessons learned.

Day 4

Soil and sediment (classroom):
What are soils and how do they form, permafrost soil, soil physical and chemical characteristics,
Contaminated soil, action levels, soil sampling and PID3 screening, sampling strategy, soil classification, packing of sample container.

Soil sampling and description (field), Soil sampling grid, different sampling methods, field classification of soil, screening.

Determination of soil properties (lab): moisture content, wet and dry weight, soil grain size analysis (sieving and settling method).

Q&A Discussion and Certification
In mid-December, 2018, we pulled onto a dirt road in central Mississippi. The ground was lightly frozen, and frost coated the trees and shrubs which blocked our view of the river. The only building nearby was an independently owned truck stop, and the steam coming from the tail pipes and vents wafted over to us in a diesel and fried-food-smelling cloud. The truck stop, however, wasn’t the only sign of civilization. The trash and the furniture we passed on our way to the river told us there had been a fairly recent encampment of homeless people in the area, though they seemed to have been driven elsewhere by the cold. The only resident left in the camp was a large stray dog, which mostly chose to watch us silently from a distance rather than bark. The river was partially frozen when we arrived, and large concretions dotted the riverbed. Within 10 minutes, we’d found our first fossil: a large tooth belonging to the extinct goblin shark Anomotodon, and we knew that this was exactly where we wanted to be.

It was only when we realized the sun was setting, and our fingers were too stiff to feel, did we leave the river and the truck stop, continuing on to New Orleans, where we packed our tools away, dressed in our best clothes and presented our research at the American Geophysical Union meeting.

This was not the first time that the itch to do field work would call to us. We were once asked to speak at our local AIPG chapter meeting. We each gave fairly straight-forward talks about animal life in the distant past. After our presentations we conversed with our friends and colleagues, answered questions from the other AIPG members, and then drove 10 hours to the Atlantic Coast of North Carolina, arriving sometime after 5:00 AM and began another expedition, digging in the Waccamaw Formation (see below) until the evening.

Going to graduate school for geology at Wright State University in Dayton, Ohio has been a life changing decision for both of us. Graduate school and the research associated with it, has inspired us not only to travel across the United States regularly, but it also led to a fundamental shift in the way we see the outcrops that make up this country and continent. The results of our educations in the field have given us the perspective needed to pass that information on to students of our own.

We are David Peterman and Ryan Shell, we’re both Ph.D. Candidates in Paleontology at Wright State University. David studies ammonites, hard shelled relatives of the squid and octopus, and how their physical properties constrained their orientation in the water, swimming efficiency, and modes of life. For the past two summers, he has driven to the Cedar Creek Anticline of eastern Montana to collect specimens. Ryan studies the ecology of Paleozoic sharks, most winters take him to the Great Plains, exploring fossil sites from southern Nebraska to central Texas looking for primitive sharks in order to learn about their distribution and habitat. Both of us have also presented our findings at conferences in San Francisco, Phoenix, New Orleans, Indianapolis, and Washington DC (as well as numerous smaller conferences, meetings, and invitations to speak).

We came into graduate school and the field of paleontology, from fairly different paths. While fossils were a topic that excited our curiosities from childhood, Ryan knew from the start that he wanted to make a living exploring the past. David, however, was undecided until his first college geology
class at Ohio State University, then gained a Master’s degree in geophysics before turning his attention to what is now his consuming interest – ammonites.

Geology, as we have come to learn, is an enormous field. A field of very diverse topics but also a field of very diverse scales. To study a single fault may take a field geologist across several hundred miles, or a single acre. We both learned this in our undergraduate work, doing field camp coursework in Montana (Ryan) and Pennsylvania (David).

The more we learned about geology, the more we wanted to travel and experience it. During his undergraduate work at the University of Arkansas, Ryan went on several field trips to the southwest, learning about national parks like Carlsbad, the Guadalupe Mountains, and Big Bend. David, after transferring to Wright State as a sophomore, explored the Carolina coast, as well as fossil sites in Texas and Kansas, during his field courses. These field courses instilled in each of us a desire to use travel to understand more about geology and paleontology, while also introducing the various difficulties of field work on the road and how to solve them. By the time undergraduate work was over and graduate school began, we were both off on our own adventures, exploring the geology of the US with our friends or by ourselves.

David became fascinated with ammonites after taking a project-based course at Wright State regarding complexity in natural systems. Ammonoid sutures are the epitome of complex natural patterns, but their function is unknown. Ammonites, in a way, present the ultimate anatomical enigma – a true challenge. Interpretations of their functional morphology and modes of life have either relied on speculation or very limited evidence. The best solution to a question with limited evidence is to gather new specimens. This led David and his twin brother into the badlands of the Dakotas and Montana for the first time in the summer of 2015. After reading research articles and making some professional contacts, they located Late Cretaceous exposures of rocks deposited from the Western Interior Seaway (a Petri dish for ammonoid evolution). This trip, and the specimens gathered, sparked David’s dissertation research on the major ammonite groups that inhabited this seaway. Shortly after, David became interested in 3D printing and the virtual reconstruction of fossils. He applied these techniques to the specimens gathered during his multiple field excursions in order to compute the hydrophysics and biomechanics of these wonderfully enigmatic creatures.

That same year, Ryan used the winter break to make his first trip to Texas in search of Permian sharks. The earliest Permian Period is one of the most well-known, and best-studied, non-dinosaur-bearing intervals in all of vertebrate paleontology. The sail-backed Dimetrodon, the boomerang-headed Diplocaulus, and the Xenacanthid shark, with its two-pronged teeth, all hail from the floodplains and rivers of Texas during this time. Ocean vertebrates, however, are almost totally unknown by comparison. While giant bizarre fishes like the buzz-saw-faced Helicoprion are known, how they fit into local fish communities and ecosystems is not. In fact, the highest number of vertebrate species ever found in a single marine deposit from this portion of earth history is only 11, and most books, if they mention early Permian marine vertebrates at all, choose to compare all ocean communities to a single site in Bolivia where only 5 species were recovered. Just as Dave’s first trip to Montana inspired research questions that lead him far down the path to a Ph.D. The quarry Ryan first explored on this trip contained a beautiful example of a community where large sharks and bony fishes swam alongside relatives of the modern Nautilus, as they hunted warm ocean waters for bluegill sized bony fishes, which hid in small reefs near the seafloor below. This community inspired him to take a closer look at these animals, a look which has taken another several years and led to a Ph.D. candidacy.

The discoveries we’ve made on these early field trips, have led to huge jumps in our research and in our professional lives. David’s work on specimens of the ammonite Baculites from South Dakota led to a fundamental shift in our understanding of how it and all other straight-shelled cephalopods swam though ancient seas. The community Ryan first glimpsed in a quarry in Texas turned out to be one of the most biodiverse fossil sites for marine vertebrates on the planet, and led him to discover 3 more fossil sites, each of them rivaling the species richness in sites explored before. This in turn led us both to utterly fall in love with field work; exploring for exploration’s sake. Over the next few years we began to collect fossils while travelling for conferences. We recovered beautiful hook-toothed mako shark teeth in the Mojave Desert when we traveled to San Francisco to present at the American Geophysical Union meeting there. We used our spring breaks to look for megalodon teeth in the Carolinas. At a Geological Society of America conference in Ames, Iowa, we took a day off and drove to the edge of the former Western Interior Seaway to explore a clam bed filled with the teeth of crow sharks and plesiosaurs. We even had time to take friends fossil hunting in Arkansas while waiting for the last pieces of Ryan’s wedding to come together. Last but not least, we began to help one another with our dissertation work: Ryan by helping to recover ammonites in the badlands during the summer, and David by sampling rocks with Ryan in Texas, Kansas, and Oklahoma during the winters. While this has all been hugely important for our own work as scientists, our relationship with field work did not change again until we incorporated what we knew into our lives as teachers. One day in the spring of 2019, while chatting with our department chair about a vacation he recently took to the Great Smoky Mountains National Park (and telling
him stories about our own adventures and misadventures that made up our spring break in South Carolina), we three realized that Tennessee contained a wealth of geological information spanning the majority of earth’s history from the Pleistocene back to the Proterozoic, and that this could all be easily communicated to our undergrads.

Despite the fact that neither of us had done any regular field work in Tennessee up to this point, we decided to construct a class titled “Geology of the Appalachian Front” and to lead juniors and seniors on a week-long field trip spanning the length of the state in the middle of the summer. We read maps and articles, consulted with other people who have worked in the region, and developed new professional contacts from scratch to design the course. In July of this year, we drove 8 students into Tennessee to view and discuss the geology of the mountains and of the foreland basin. In the western part of the state we explored Cretaceous rocks for beautiful fossil snails, ammonites, sharks, and even the occasional reptile. In the Valley and Ridge Province we talked about the deposition in the early basin in the Paleozoic from road-cut to road-cut as well as broad scale deformation. In the Blue Ridge we stayed together in a cabin high in the forest near Gatlinburg. In the mountains we found fist sized garnets, staurolites, even olivine and rubies from deep within the core of the Blue Ridge. We hiked to White Oak Sinks in the national park one day and saw Proterozoic rocks thrust on top of Ordovician limestones, the water conducted along the fault carving out deep caves. Our students loved it! Our favorite feedback was that our students became re-invested in their work in the classroom having seen how clearly the lessons learned in geology courses can translate to actual rocks.

This spring (2020) we plan to teach another field course called “Atlantic Coast Paleoecology” which will take place in and out of fossil sites and motels from southern Virginia to central, SC. Our students will search for (and discover, we hope) the difficulties near-shore animals faced as the Miocene epoch graded into the Pliocene and Pleistocene: thermal optima and glaciations waxing and waning. We will also take them to a coastal island where they can see firsthand what living near-shore communities are like in the region. This should give them a new perspective on the history of these ecosystems during the last 7 million years.

As we have mentioned earlier, Geology is a broad science. Its realm of interest is essentially an entire planet and the processes and features of that planet. Going to graduate school in geology was one of the best decisions either of us have ever made because it allowed us to gain a better understanding of the scale and complexity of these processes and features.

Continued on p. 56
Field Trips
Link Students to Rock Resources

Michael T. May, Ph.D., P.G., MEM-0586

Dr. Michael May’s teaching and research interest at Western Kentucky University includes integration of technologies such as geophysics and digital maps and data with field data, teaching students field geology, environmental geology and sedimentology/stratigraphy as related to resource identification and environmental management.

Many of us who are “older” and have been involved in the industry for decades such as in oil & gas, environmental geology and hydrogeology, litigation-support geology (expert witness), and academia, have already had our epiphany regarding the inherent value of field trips, especially those that linked the resources to the rocks or sediments. As the cliché goes, experience is the best teacher, and as my wife and I have told our young adult sons, all experience is good experience even if it includes a “bad” experience now and then, such as a blizzard on the first day of summer doing field work in Wyoming, or seemingly endless high heat and humidity with chiggers in the east. Another well-worn statement many geologists bat about is that the worst day in the field is arguably better than a great day in the office! Perhaps I am showing my age and pine for the good ‘ole days of eight-week long field camp experiences including seeing classic stratigraphic sections and structures in the Rocky Mountains and associated mappable yet challenging surface exposures. Today however, as geology is involved with more multi-disciplinary and transdisciplinary teams and as universities continuously attempt to minimize costs, there are fewer and fewer multiple-week field camps that students attend, or at least it appears to be so over the last 20 years (e.g. Drummond, 2001 - http://www.nagt.org/files/nagt/jge/columns/Editorial-v49n4-FieldCamps.pdf). A partial antidote for this situation is to have students engaged in more frequent field experiences, albeit ones of shorter duration. These opportunities can still provide multiple examples of various resources related to the rocks or even the unconsolidated deposits that we study in geology. At the university at which I teach, a field course of an extended nature is highly encouraged, but the reality is that many students work during summers to pay more and more for their tuition, since Kentucky, like many states, has been decreasing higher education funding for over a decade.

An alternative is thus multiple field experiences totaling six credit hours, such as enrollment in an Introductory Field Methods course in which students participate in regional trips in Kentucky and adjacent southern Indiana and northern Tennessee, followed by a week-long field course during spring break in Death Valley, or, in some years Hawaii. The field methods course is typically a three-to-four hour immersion into local geologically interesting areas (less than 25 miles away) and a weekend trip to important sites within a two to four-and-one half hour drive away (e.g., Falls of the Ohio State Park featuring mostly Devonian “reef” outcrops, and Pound Gap Mississippian-Pennsylvanian road cut on the KY/VA border in the Appalachians etc.). The week-long field course is generally prepared for with on-campus class meetings.

Many of these field areas near the university are easily accessible and we make eight to ten trips per semester into the field. Where students are able to integrate online database information such as oil and gas well records, they can tie measured stratigraphic sections from road cuts or other exposures to subsurface databases by construction of subsurface maps such as structure contour or isopachs. They are asked also to integrate aerial photos, elevation data and some LIDAR data with field excursion note taking. Some of the salient experiences include understanding resources that are associated with the local stratigraphic units such as groundwater, springs in karst areas, asphalt rock in quarries, and dimension stone (for building) in quarries, or sand and gravel deposits in glacial outwash areas in the Ohio Valley. These various experiences may not be full-fledged field courses or a field camp but collectively they are memorable, educational and create student cohorts that aid in building geology programs.

Hopefully, your university recognizes your need to avail yourself of as many field opportunities as possible as you go through your undergraduate careers as budding geologists. In addition to courses on campus, or even if you are fortunate enough to participate in a summer field course of several weeks duration, you should also strive to be as active as you can in professional societies that offer field trips or field conferences. The Geological Society of America, American Association of Petroleum Geologists and in particular, the AIPG for various states, such as in my region of KY, IN and IL, offer great field conferences that commonly focus on resources in rocks. Just some examples of recent note include: 1) an excellent trip sponsored by the IN-IL AIPG to see the great exposures of Indiana (Salem) Limestone used for building many structures in the USA (replete with hardgrounds, high-energy stromatolites, and great sedimentary structures – Figure 1), 2) a field trip giving students study access to a great unconformity between the Mississippian and Pennsylvanian in KY, and associated...
asphalt rock quarries (Figure 2), 3) fossil exposures (biostratigraphic resources) in the Louisville area at the Falls of the Ohio State Park (Figure 3A and 3B) and 4) collecting and analyzing strike and dip and related data for paleocurrent analysis of either ancient rivers in the Pennsylvanian or tidal channels in marine sandstone in the Mississippian. Most field experiences also are important for you as a student to practice the skills of note taking, making various measurements and learning to connect to online databases that place your field experiences or studies into context for others now and for the future.

The best advice that I can give is that you should attend regional field conferences as much as possible and that you should research whether there are student rates available, as almost all organizations still believe strongly in students participating at little or no cost (e.g. AIPG in Indiana this past year was free for students and GSA and AAPG also provide discounts for regional and national meetings). Geology clubs at universities are great groups to join to also plan your own field trips, or you can choose to join in the fun and meet experts in their element in your region as a club activity. Happy Trails!
EXECUTIVE DIRECTOR’S MESSAGE

One of the joys of parenthood is meeting other parents. Those folks whose children become friends of your children. You meet them at basketball games, and school concerts, at the science fair, and at dozens of other events that are part of your child’s world. Almost always, these meetings and the questions you are asked by your new acquaintances are perfunctory. How are you? What do you think of Drew Lock (the new Bronco QB)? Where do you work? And a myriad of other questions that occasionally spur interesting conversations. If you saw my TEDx talk, you’ll know that it was during one of these conversations that a parent mistook geology for gerontology, and exclaimed, “it must be fascinating to work with the elderly.”

One parent asked, “what was the most fascinating thing you have ever cleaned up?” I was taken aback. In the 15 years I’d been a parent, no one had ever asked that question when I told them I had worked as a field remediation technician for an environmental consulting firm. Furthermore, I had never thought of any of the materials I helped to remediate as fascinating. Toxic? Absolutely. Dangerous? Without question. Gross and nasty? Often. But fascinating? No, I never really thought of those things as fascinating. I paused for a moment and answered honestly. I told the parent that I had helped to clean up some nasty, dangerous, toxic stuff, but that I had never really thought of it as fascinating. This parent followed up by stating that even though the stuff was nasty, the work must be fascinating. On that point, the parent was right.

When I think back, I have participated in some fascinating remediation projects. I did lead abatement at a local indoor shooting range, cleaning 300-foot indoor rifle tubes that were 3 feet in diameter. I cleaned up wrecked train cars filled with animal fat that was supposed to be going to a rendering plant. I worked on a low-level (mostly alpha-particle) radiation project. Looking back, the work I did WAS fascinating. I just didn’t see that at the time.

When that parent asked about the most fascinating thing I’d helped to remediate, I was at first surprised, and then excited. I was excited because their interest was genuine, and as I began to tell some of the stories from that part of my career I saw their fascination, excitement, surprise, horror, and laughter at all of the things that I’d worked on over that time. I told them about shoveling congealed animal fat out of wrecked train cars, cleaning up radioactive waste, pumping and treating groundwater that was contaminated with furfural1, cleaning up indoor firing ranges, and using carbon dioxide while cutting open fuel tanks. As the conversation wound down, I realized that they were right. What I did was fascinating. As we parted, the parent told me they had no idea that geologists did those kinds of things.

Being a professional geologist IS a fascinating, rewarding, fulfilling, career. The work we do spans a broad variety of areas, from water resources, to exploration, to prospecting, to risk management, to remediation; in reality, our work underpins all of modern society. We geologists, though we are a small profession with fewer than 35,000 members working in the United States, have an outsized impact. We find the resources needed to manufacture our neighbor’s iPhone. We locate and exploit energy resources. We identify and manage water and treat the wastewater we generate; we work with engineers to insure that the substrate will support whatever infrastructure is being built. We provide sound information for policy makers and provide critical details with respect to physical properties of Earth materials so that engineers and modelers can make accurate assumptions necessary for their work.

Why then, are most people unaware of the impact that our work has on their everyday lives? I’m not sure, but I suspect at least three things (and probably more) are at play. First, we are a small, highly technical profession. As such, we don’t have a large public presence in the way that lawyers, or doctors, or CPA’s or even cosmetologists do. The size of our profession limits our public visibility. Second, I believe geologists tend to prefer to stay out of the limelight. Many of us became geologists because we enjoyed our time in the field, alone or as part of a small group. I personally find those field opportunities to be among the most rewarding and fulfilling of activities. Third, geology lacks a public face, a personality that immediately brings our science to mind. Other disciplines have had those personalities; the names immediately bring to mind an image. Marlon Perkins and Jim Fowler2, The Crocodile Hunter, Dr. Oz and Dr. Phil, Michio Kaku, Neil DeGrasse Tyson, Richard Feynman, and Einstein. Perhaps Roald Hoffman is not quite the same household name, but he communicates chemistry to a wide audience. Geology lacks such a public superstar.

I’ve come to believe that we don’t tell our stories often enough. We talk to each other, but we really don’t tell those stories to people outside the profession. I hope we change that. I hope we begin to share these stories and I hope we share them far and wide. We provide information critical to all infrastructure construction, and find the resources that are necessary for our future. Without geoscientists our civilization would be impossible: I encourage all of us to tell that story more often, and to tell it with a conviction that is befitting the importance of our work.

I hope that each of you has a warm and lustrous winter.
Best Wishes,
Aaron

---

1. Furfural: a colorless liquid used in synthetic resin manufacture, originally obtained by distilling bran. $C_6H_4OCHO$

Aaron W. Johnson, MEM-2783
awj@aipg.org

Telling Our Story

1. Furfural: a colorless liquid used in synthetic resin manufacture, originally obtained by distilling bran. $C_6H_4OCHO$
It is my honor and a privilege as President of AIPG to welcome members on this New Year of 2020. I joined AIPG in 2008 and became the Tennessee Section President in 2013. That led to my first trip to the annual AIPG meeting, in Colorado in 2013, where I was elected to the Advisory Committee for 2014 – and I thank Bill Siok and Larry Weber for the encouragement to get involved on the national level. After my experiences at the annual meeting and my year on the advisory board, I was “all in” on AIPG. I have truly enjoyed the networking and interaction with geologists from various disciplines, including academia, regulatory, mining, and consulting. I encourage students and young professionals to take advantage of the opportunities that AIPG offers, since the relationships you develop early in your career will last a lifetime. The wealth of knowledge that professional members can convey to students and young professional members will be invaluable to your careers. Make 2020 the year that you get involved and plan to attend section meetings, plan a field trip, attend the annual meeting, or write an article for TPG.

As many of you know, AIPG would not be the organization it is today without the dedicated staff at headquarters. I look forward to working with Executive Director Aaron Johnson, Assistant Director Wendy Davidson, Professional Services Manager Cathy Duran, and the other staff at headquarters including Cristie Valero, Dorothy Combs, Mona Scott, Kathy Glivar, and AASG Administrative Assistant Lauren Zeek.

The 2020 Executive Committee is comprised of an excellent group of professionals. I truly enjoy the opportunity to work in a diverse and inclusive environment and I hope AIPG will continue to foster this environment as we grow and solidify our membership. There is a good chance this topic might come up again in another message.

I look forward to the opportunity to continue serving with Past-President Keri Nutter (Alaska). Her enthusiasm is infectious, she is an asset to AIPG, and just a great person to be around. Keri and I served together as advisory board representatives and I look forward to working with her again. Nancy Wolverson (Nevada) will remain on the board transitioning from Vice President to President-Elect. I am happy to continue to work with Nancy and hopeful that by the end of 2020 I will be able to correctly pronounce Nevada. Dawn Garcia (Arizona) is returning to serve on the Executive Committee as Vice President in 2020 and will continue to provide Arizona representation on the board. Dawn served as the Arizona Section President in 2019. Sara Pearson (Michigan) will serve as Secretary in 2020. She has been an integral part of the Ethics Committee serving as Chairperson. I have not had the opportunity to work with Dawn or Sara, so I am looking forward to the opportunity in 2020.

Matt Rhoades (Missouri), and John Berry (Texas) will maintain seats on the ExCom serving as the 2020 Treasurer and Editor, respectively. These two are prime examples of members that can convey a wealth of knowledge just by telling stories of their career adventures and I look forward to serving with them again. Jessica Davey from Colorado will serve as our Young Professional as Erica Stevenson transitions to the Past-Young Professional in 2020. The young professional positions have been an excellent addition to the Executive Committee and I look forward to working with both of them in 2020. The advisory board, as elected in Burlington in September, will be Steve Baker (California), Colin Flaherty (Ohio), and Shanna Schmitt (Minnesota), who are returning as advisory board representatives from 2019. They will be joined by Andrew Jones (Kentucky) who joins the Executive Committee for the first time.

I am excited for the opportunities in 2020 to focus on the development of students and young professional members through on-line learning initiatives and networking events on a national and sectional level to foster interaction with our professional members. Students and young professionals are the future of AIPG and we need to continue to focus on retaining students after graduation so they transition to young professional status. AIPG will continue to promote advancement of the profession of geology and to advocate for the profession before government and the general public. This will include a continued partnership with ASBOG as we develop a new membership category that will incorporate state licensing requirements in response to recent attempts to deregulate professionals and continuing education. AIPG is also in the process of updating and adding to our position statements, so stay tuned for more to come on this initiative. I am excited to get to work in 2020 serving the members that make AIPG such great organization. Thanks for the opportunity!

Students and young professionals are the future of AIPG and we need to continue to focus on retaining students after graduation so they transition to young professional status.
1. This intrusive, phaneritic igneous rock is composed primarily of plagioclase feldspar with additional mineral components including quartz, biotite and hornblende:
   a) Dunite.
   b) Rhyolite.
   c) Granodiorite.
   d) Andesine.
   e) Man, let’s say that igneous rocks are just not “cool”...

2. In our studies of crystallography, consider a crystal phase which cuts the “a”, “b” and “c” orthogonal axes at values of 1, 1 and 2, respectively. In terms of its “Miller Indices”, what is the proper notation for this crystal phase? (Axes “a” and “b” are horizontal, while “c” is vertical).
   a) (112).
   b) (212).
   c) (221).
   d) (121).
   e) Who’s Miller?

3. Amongst the gases that may be emitted in volcanic activity we find water vapor and hydrogen chloride. Given the molecular weight of water as $\approx 18.02$, the atomic weight of oxygen at $\approx 16.00$ and the atomic weight of chlorine $\approx 35.45$, what then is the molecular weight of hydrogen chloride?
   a) 36.46.
   b) 34.08.
   c) 20.01.
   d) 64.06.
   e) Dude, I are nut a ggkimist; I are mor uf an astorficisit miself.....

4. The choice below depicts a group of tube-shaped, ring-shaped or box-shaped marine bivalves that appeared in Jurassic time and which became diverse as well as major reef builders before their extinction at the end of the Cretaceous:
   a) Cycads.
   b) Ammonites.
   c) Rudists.
   d) Serpulids.
   e) Hey hombre, quién sabe? It might be this or it might be that....It’s time for another cerveza...

5. The principle of cross-cutting relationships is attributed to:
   a) Abraham Werner.
   b) Nicolas Steno.
   c) Marie Curie
   d) The Barber of Seville.
   e) Bubba the Butcher.
It is the Greatest Love/Hate Relationship You Will Ever Have – Field Camp; an Experience no Student Should Ever Miss.

Valarie Smith, SA-1869

I began my academic career in geology nine years ago, completing an undergraduate degree, a master’s degree, and I am now nearing the end, finishing up a PhD in structural geology and geochronology at Florida State University. This experience has been a wonderful journey that has challenged me academically, physically, and emotionally beyond my wildest imagination. However, some of my greatest memories are my experiences in field camp as a student and as a graduate teaching assistant.

My undergraduate program did not have a field camp course, so I attended one hosted by another university, in the Black Hills of South Dakota and Wyoming. I got to meet students from all over the U.S. and have remained friends with several of them through social media over the past seven years. I would describe my experiences in field camp as a love-hate relationship that, when all is said and done, was agony and exhilaration at the same time. Even though I was exhausted at the end of my field camp course, I was ready to return and repeat the whole process all over again.

There was one day in the field that sticks out in my mind vividly. My mapping partner and I were traversing across a mountain, near a small town whose name I cannot recall, following an outcrop. We decided to make our way down a slope to continue following the outcrop along a creek bank below. Being the first to descend down the slope, I stepped on a pile of pine straw covering the face of a slate outcrop and down I went. I slid down this rock face 15 feet across pine straw and pine seedlings and came to an abrupt stop straddling a small tree. Needless to say, I not only cleared the way for my mapping partner, I was angry and irritated at my stupidity and misfortune. At this point in the field camp course, we had already completed three projects, I had worked with partners that were less than desirable, and had been away from home and my husband for four weeks, living with a varied group of personalities and attitudes, and I was over it. I stomped around, exclaiming profanities for about ten minutes. What a mess. I must have looked like a woodland wild child, jumping around like a crazy person. Once the rage was over, I went to the creek, washed off my hands and face, dug pine needles out of my underpants, collected my equipment, and returned to the mapping project.

Continued on p. 43
Answers:

1. The answer is choice “c” or “Granodiorite.” Dunite is also an intrusive, phaneritic igneous rock, but composed mainly of olivine, with pyroxene and possibly chromite, magnetite and pyrope. Rhyolite is an aphanitic igneous rocks composed primarily of alkali feldspar with additional plagioclase feldspar and quartz. Rhyolite may also exhibit a porphyritic texture with phenocrysts of quartz and alkali feldspar surrounded by a fine-grained matrix. Andesine is not a rock, but a plagioclase feldspar mineral (Ca,Na)(Al,Si)_{2}O_{8}.

2. The answer is choice “c” or “(221).” The “Miller Indices” of a crystal phase consist of a series of whole numbers which have been derived from the axial cut parameters through their inversion and subsequent clearing of fractions, if necessary.

Thus, for a crystal phase with parameters 1a, 1b and 2c, upon inversion we obtain:

\[
\frac{1}{1}, \frac{1}{1}, \frac{1}{2} 
\]

Clearing fractions (e.g., multiplying by “2”) we can express the Miller Indices of the crystal phase as:

\[
(221) 
\]

The above notation is the answer to our question.

3. The answer is choice “a” or “36.46.” Remember that the molecular weight of a compound is the sum of the atomic weights of all the atoms of the molecule. For water (H_{2}O) the molecular weight is:

\[
2(X) + 16 = 18.02 \\
2X = 18.02 - 16.00 = 2.02 \\
X = 1.01 
\]

“X” in (3) is the atomic weight of hydrogen = 1.01

Similarly, for hydrogen chloride (HCl), the molecular weight is:

\[
1.01 + 35.45 = Y \\
Y = 36.46 
\]

Thus, 36.46 is the molecular weight of hydrogen chloride (HCl = 36.46) and the answer that we seek.

Choice “b” is the molecular weight of hydrogen sulfide (H_{2}S = 34.08). Choice “c” is the molecular weight of hydrogen fluoride (HF = 20.01). Choice “d” is the molecular weight of sulfur dioxide (SO_{2} = 64.02). These additional gases may also be emitted by volcanoes. About the three most common volcanic gases are water vapor (H_{2}O), carbon dioxide (CO_{2}) and sulfur dioxide (SO_{2}).

4. The answer is choice “c” or rudists.

Cycads are seed plants with a long fossil history (dating back to the Permian period) that were formerly more abundant and diverse than at present. They generally have a stout/woody trunk with a crown of large, hard and stiff, evergreen, pinnate leaves.

Ammonites are not bivalves or reef builders, but mollusks (cephalopods) which lived during the Jurassic to Cretaceous time frame.

Serpulids are sessile, tube-building annelid worms that attached themselves to rocks, algae, etc. The earliest found in the geologic record date back to around Permian time.

5. The answer is choice “b” or “Nicolas Steno.” Nicolas Steno (1638-1868) was a Danish scientist who later became a Catholic bishop. His contributions to geology also include the principles of initial horizontality and lateral continuity, the law of superposition and the law of constant angles (the first law of crystallography). His work with modern-day shark teeth and those present in sedimentary rocks led him to theorize how solid objects can be found inside other solid objects. He agreed with his predecessor, Leonardo da Vinci, as well as with his contemporaries, Robert Hooke and John Ray, in recognizing that fossils were once living organisms.

Abraham Werner (1749–1817), the father of German geology, was a proponent of the early theory of stratification known as Neptunism. While Neptunism was eventually invalidated, Werner is remembered for demonstrating the chronological succession in rocks, as well as for being an inspiring speaker, influential geologist and a knowledgeable descriptive mineralogist.

Marie Curie was a Polish and naturalized-French physicist and chemist who conducted pioneering research in the field of radioactivity. Madame Curie was the first woman to win a Nobel Prize. She also had the distinction to become the first person and only woman to win it twice in two different sciences.

The “Barber of Seville” is a well-known opera by Gioachino Rossini.

I think I ran into “Bubba the Butcher” at a dentist’s office some years back.
Geoethics and responsible use of geo-resources

“Geoethics and responsible use of geo-resources” is the title of a 15.5-minute video by Giuseppe Di Capua of the International Association for Promoting Geoethics (IAPG), which is available at https://youtu.be/23nwwu79sSA. Di Capua defines “sustainable development” as, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” He goes on to state that, “Responsible mining demonstrably respects and protects the interests of all stakeholders, human health and environment, and contributes discernibly and fairly to broad economic development of the producing country and to benefit local communities, while embracing best international practices and upholding the rule of law.” He refers to the IAPG’s White Paper on Responsible Mining, http://www.geoethics.org/wp-responsible-mining, that contains a listing of 15 best practices for mining. Di Capua concludes that, “In responsible mining, dialog is the key.” Di Capua presents some interesting ideas and does recognize that mineral deposits are depletable, occur where they are found regardless of the location’s desirability (as measured in some way), and that their extraction results in both undesirable and desirable consequence from a social and environmental perspective. As the preamble to the White Paper concludes, “There is no doubt that mining can bring positive benefits to the host countries, but these can come at a cost to the environment and local communities if relationships, resources and operations are not managed properly. The fundamental aim must be equitable distribution of the benefits of development and minimization of the negative impacts on people and the environment. Responsibly navigating this field requires a strong ethical compass.” “Equitable distribution” is a loaded term. Who decides what is equitable? Choices must be made and not everyone is likely to be pleased with the choices made. Di Capua’s lecture is worth 15 minutes of your time and can count as CPD, depending on your specialty and interests.

Is a fully compliant report always needed? What if it can’t be afforded?

Betsy Suppes, a colleague of mine, posed the following question, “I did an appraisal on a property in Indiana County, PA. The value of the oil and gas rights was not very high (about $500/acre) and the client had 42.5 net mineral acres (est. worth $21,500). I spent a heckuva lot of time researching leasing and comparable sales and then presenting the results, then justifying my valuation. The property had 3 conventional wells which were limping along, but provided a small revenue stream to the owner, plus ‘house gas.’ When you have a sense that a client’s oil and gas rights are not worth much, should you do a ‘full’ appraisal anyway? As it was, I took a $1,400 haircut plus my draftsman took a $600 haircut. Some of the things that a reviewer of Suppes’ appraisal report suggested would have added another $1,000 to the appraisal. It would have ended up being close to $6,000.”

Suppes was preparing a mineral value appraisal report and such reports are usually expected to contain specified types of information based on expected investigations in order to considered fully compliant appraisals. Mining reports done for NI 43-101 or the JORC Code similarly call for inquiry into and discussion of specific topics in order to be fully compliant with NI 43-101 or the JORC Code. These are examples of the “fully compliant report” named in the title of this topic. Evaluations of the environmental characteristics of a site and an archeological survey of an area are other examples of work where a “fully compliant report” that meets a specified regulatory standard. The amount of work required and therefore the cost to prepare a “fully compliant report” will vary considerably depending on the type of report, the size of the property, and the amount of information available about the property. The types of information required for full compliance will obviously vary widely depending on the specific geology and history of the property. Finally, geoscience professionals should be paid a reasonable fee for their work and have their expenses covered.

Part of the problem with this assignment was the client’s failure to:

• fully describe the interests held (only 50% rather than all)
• mention that there was production on the land
• have accurate maps and documents regarding the lease
• have stubs or other records of the royalty checks received.

Topical Index-Table of Contents to the Professional Ethics and Practices Columns

A topically based Index-Table of Contents, “pe&p index.xls” covering columns, articles, and letters to the editor that have been referred to in the PE&P columns in Excel format is on the AIPG web site in the Ethics section. This Index-Table of Contents is updated as each issue of the TPG is published. You can use it to find those items addressing a particular area of concern. Suggestions for improvements should be sent to David Abbott, dmageol@msn.com

Compiled by David M. Abbott, Jr., CPG-04570
5055 Tamarac Street, Denver, CO 80238
303-394-0321, dmageol@msn.com
Working with unsophisticated clients can be difficult because they lack records and often have an inflated view of a property's value. Letters of engagement or work scope can help describe what information and documents are needed in detail from the client and the consequences of not having the needed documentation, that is, higher costs.

When a client initially requests a report, the consultant should be able to provide an estimate of the fees and expenses that will be incurred to produce a report of a specified level of compliance. It is during these initial discussions about the scope of work requested that the client and consultant can come to conclusions about the estimated costs of the work versus the expected benefits. If the client is unwilling to pay the estimated costs of a “fully compliant” report, discussions about the purpose to which the report is to be put may identify acceptable alternatives. But if full compliance is required, the consultant cannot ethically cut corners in order to lower a report’s costs. To do so could have significant adverse consequences to the consultant’s reputation and also to client’s ability to move a project along.

Game of Mines and sampling QA/QC

Paul Fell’s “Game of Mines” elsewhere in this issue addresses important issues of Quality Assurance and Quality Control in sampling programs. Although Fell uses mining examples, his major points about the need to determine the accuracy of sample results (closeness to actual value), the precision of those results (repeatability), lack of contamination of the samples and/or cross-sample contamination in the preparation and analytical steps, and determining the accuracy of the sample’s location in X, Y, Z space are critical to any sampling program. Fell points out the Dilution of Position (DOP) location precision value for GPS coordinates that depends on the number and relative positions of the satellites the GPS unit reads. The PE&P index.xlsx file for this column contains 19 entries for “quality control” that address aspects of QA/QC programs, including examples of some failures both intentional and unintentional. Everyone should read Fell’s article.

Atmospheric CO₂

My article in this issue examining the responses to AIPG’s Climate Change Questionnaire was intentionally neutral, although I’m sure some will object to that characterization asserting bias of one sort or another as illustrated by the comments received with the questionnaire. I recently did a bit of research on atmospheric CO₂ reflecting on things I learned about coal geology and mining. Miners have worried about mine gas composition compared with normal atmospheric composition for a long time and for obvious reasons having nothing to do with the climate change debate. They also take note of the effects of altitude on respiration due to reduction in the amount of air per cubic volume (barometric pressure). The dry atmosphere contains nitrogen 78%, oxygen 21%, argon 0.93%, CO₂ 0.04% (410 ppm), and trace amounts of other gases including methane, 1.7 ppm; the % is by volume. Water content is highly variable but is generally around 1% (https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html, accessed 11/15/19). Robert Peele’s Mining Engineering Handbook, 2nd ed., 1927, states that atmospheric CO₂ is 0.03% by volume (amount given in a table on p. 1556 although a footnote states that CO₂ can vary from 0.025% to 0.035% when measured about 3 feet above the ground, and that the London Fog’s reported CO₂ was 0.14%). The difference between 0.03% and 0.04% is 100 ppm. The world population was estimated at 2 billion in 1927 and is over 7 billion now (https://en.wikipedia.org/wiki/World_population#Modern_history, accessed 11/17/19). Thus human-generated amounts of CO₂ from burning coal, oil, and gas can be significant in the 0.01% increase in atmospheric CO₂ between 1927 and now.

Compiler’s Note

This is a shorter than normal column for two reasons. First, I spent a good deal of time in November analyzing and writing up the results of AIPG’s Climate Change Questionnaire which appears elsewhere in this issue. And second, this is the annual student issue with many contributions by and for students. I’ve contributed enough to this issue.

1. John Berry, who grew up in England, points out that such fogs were known as “pea soupers” or “smog.”
There are many stories like mine and every field camp student can tell you their own colorful rendition. However, most students agree, even though field camp is one of the most challenging geology courses you could take, physically, mentally, and emotionally, it is one of the greatest experiences you will ever have as a student. You learn so much about how to apply geologic concepts to real world problems, and you learn a lot about yourself. You get to see some of the most beautiful landscapes that you have ever seen, and the stories you return with will be conversation pieces for many years to come.

If you are considering taking a field camp course, I encourage you to not hesitate and enroll in the class. If your school does not offer a field camp course, attend one at another university. Florida State University (FSU) offers an affordable field camp course that is open to any qualifying student. It is a comprehensive, six hour geology course centered on interpretations of field data collected by students in the forms of detailed geologic field maps, basin analysis/stratigraphy, and field-based geophysical observations. There is a four day geologic field trip through southern Colorado that is spectacular. Participating students apply basic geologic principles and concepts learned throughout their academic work in their geoscience programs to solve a number of varied and complex problems associated with different kinds of geologic settings.

This course is perfect for graduating geology seniors who are transitioning to professional careers (industry, consulting, state/federal agencies) or going onto graduate school. The FSU field camp course is taught from early May to the middle of June in the southern Rocky Mountains in northern New Mexico, a scenic area where the Rio Grande Rift splits the Sangre de Cristo and Brazos Mountains. For more information, please visit the FSU Earth, Ocean, and Atmospheric Science (FSU EOAS) website (https://www.eoas.fsu.edu/undergrad-degrees/geology/summer-field/).

Field Camp, you will love it, you will hate it: it is the greatest experience you could ever have as an undergraduate geology student.

About the Author

I attend Florida State University as a Structural Geology PhD candidate and undergraduate geology adviser. I received two undergraduate degrees from the University of West Georgia in Carrollton, Georgia, in Middle Grades Education and Geology, and I hope to share with others my love of the natural world through community outreach, work, and education.
Short non-fiction films were initially called “actuality” films. The term “documentary film” was coined by the Scottish filmmaker John Grierson in 1926 in his review of Robert Flaherty’s film Moana (showing the traditional life of people in Samoa). Documentary films are valuable tools for teaching and learning in every field of science, but especially so in geology courses. The reason is simple: Geology is a highly visual and graphical science. Remove maps, photographs, and illustrations from a geology textbook and what will be left is like a featureless face. Indeed, geological discoveries and concepts about minerals, rocks, strata, faults, folds, intrusions, inclusions, unconformities, and so forth have been made visually, not in an abstract way. The only other science that is highly visual and pictorial is biology. However, data visualization by computer coding and processing is now in high demand in every field of science. This trend highlights the future importance of documentary films in science education. But there is another reason for using films in the classroom: no matter how much our professorial voice is pleasing to us or to students, at times it becomes tiring for both parties. An occasional change is needed, and documentary films provide exactly that. So there is a combined audio-visual reason for using documentary films.

How to use these audiovisual materials in classes? I use them in three different ways: First, short video clips can be inserted in the PowerPoint files of lectures so that they can be accessed and watched during the class; these clips enhance the material covered in the lecture. YouTube and some other websites have a large number of short video clips on various topics related to earth and environment sciences. Second, instead of a regular lecture, we sometimes have a “movie time.” Then students can watch an entire 60-minute documentary in the class. Third, I give students an assignment to watch a particular documentary film and write a brief report on 10 interesting things they learned from the film. There are a large number of documentary films on earth science, the environment, natural resources, natural hazards, earth history and so forth. The following are 10 films (or film series) which I have watched; I have also used many of them in geology courses. These are general earth science films; there are also documentaries about individual topics like earthquakes and volcanoes, which are not included in the following list.

(1) Living Rock: An Introduction to Earth’s Geology

(2) Earth Story

(3) The Habitable Planet: A Systems Approach to Environmental Science
(Annenberg Media, 2007). DVD package contains 4 discs. Thirteen program, each running 30 minutes. Titles include: Many planets, one Earth; Atmosphere; Oceans; Ecosystems; Human population dynamics; Risk, exposure and health; Agriculture; Water resources; Biodiversity decline; Energy challenges; Atmospheric pollution; Earth’s changing climate; Looking forward: our global experiment.

(4) Earth: The Biography
(BBC, 2008, 230 minutes). Original BBC title in the UK is Earth: The Power of the Planet (2007). Presented by Dr. Iain Stewart, a Scottish geologist and professor of geoscience and communication at the University of Plymouth. Also aired on the National Geographic Channel. Five episodes: Volcanoes; Ice; Atmosphere; Oceans; The uniqueness of planet Earth that allows for life. DVD package has 2 discs. The film is accompanied by a book, Earth: the biography, by I.S. Stewart and J. Lynch (National Geographic, Washington D.C., 2008).

(5) Faces of Earth
(Science Channel, 2008, 180 minutes). Presented by Maurice LaMarche. Episodes include: Building the Planet; Shaping the Planet Earthquakes; Assembling America; Human World).

(6) How the Earth Was Made
(The History Channel) How the Earth Was Made was first produced by Pioneer Productions for the History Channel in 2007. The first film was a two-hour special exploring the geological history of the
Earth aired on December 16, 2007 (DVD release in 2008). It was written and directed by Peter Chin.

In 2009 (February 10-May 5), How the Earth Was Made continued in a 13-episode program: San Andreas Fault; The Deepest Place on Earth; Krakatoa; Loch Ness; New York; Driest Place on Earth; Great Lakes; Yellowstone; Tsunami; Asteroids; Iceland Volcano; Hawaii; The Alps. DVD package, How the Earth Was Made: The Complete Season 1 (2009) has 4 discs (450 minutes).

The second season episodes were aired November 24, 2009 to March 2, 2010. DVD package, How the Earth Was Made: The Complete Season 2, with 4 discs (610 minutes) was released in 2010. Its 13 episodes include: The Grand Canyon; Vesuvius; Birth of the Earth; Sahara; Yosemite; The Rockies; Ring of Fire; Everest; Death Valley; Mt. St. Helens; Earth’s Deadliest Eruption; America’s Ice Age; America’s Gold.

(7) How the Earth Changed History
(BBC, 2010, 300 minutes). Original UK title: How Earth Made Us. Presented by Dr. Iain Stewart. Travelogue, history and geology. Five episodes (each 60 minutes). DVD package has 2 discs. Five one-hour films on how geology, geography and climate have influenced the evolution of mankind. Five episodes include: Human Planet; Fire; Wind; Water; Deep Earth.

(8) Inside Planet Earth
(Discovery Channel, 2010, 90 minutes). A journey from the Earth’s surface to the fiery core.

(9) The Rise of Continents
(BBC, 2013, 240 minutes). Presented by Dr. Iain Stewart. DVD package has 2 discs. Aired on BBC Two in June 2013. Episodes include: Africa; Eurasia; The Americas; Australia.

(10) Earth: The Inside Story
(Earth Images Foundation and PBS, 2016, 60 minutes). Written by Doug Prose. Narrated by Dan Nacktrab.

Like many others, I am a big fan of documentary films and have personally learned very much from them. The above annotated listing is the tip of an iceberg in the genre of documentary films in natural science. A comprehensive bibliography or database of documentary films would be a very valuable reference work.

But there is another reason for using films in the classroom: no matter how much our professorial voice is pleasing to us or to students, at times it becomes tiring for both parties. An occasional change is needed, and documentary films provide exactly that. So there is a combined audio-visual reason for using documentary films.

“Documentary film is a factual film which is dramatic.”
Pale Lorenz, American film critic
Radon: Invisible Killer

Michael Urban, Ph.D., MEM-1910, Department of Professional Education, and Julie Curtis, Ph.D., Department of Nursing, at Bemidji State University in Minnesota

What do you visualize in your mind’s eye when you hear the word geology? Is what you envision the same as what the average citizen conjures up? I daresay not. The operational knowledge about geology an ordinary citizen possesses probably relates to those aspects of the discipline that are the most frequently encountered, obvious, or relevant.

Potentially catastrophic events like earthquakes and volcanic eruptions are often so devastating and unexpected that they capture the attention of the whole nation. The high visibility and large death tolls associated with these phenomena can make them unforgettable, lending themselves to immediate recall when we hear the word geology. Would our nation’s citizens easily believe that there is an even more sinister geologic hazard lurking around us every day, claiming tens of thousands of lives each year, and that this hazard is neither visible nor typically reported about in the news? Well, we know that there is, and this hazard is called radon gas.

Unobservable Geology: Radon

Radon is an invisible, odorless noble\(^1\) gas and is considered an indoor air quality pollutant. Since radon is a gas, it may be inhaled with every breath of air we take and exhaled again with the other normal by-products of respiration. As a gas, radon is unreactive and poses no problem for us at the atomic level. Despite this seemingly hospitable chemical demeanor, and perhaps surprisingly, the element radon is the second leading cause of lung cancer in our country (Centers for Disease Control and Prevention, 2019a). The reason for this apparent incongruity is found at the subatomic, or nuclear, level: all isotopes of radon are radioactive (Stwertka, 2002), with the most stable and longest-lasting \(^{222}_{86}\text{Rn}\) having a half-life of 3.8 days.\(^2\) It is this radioactivity that creates our problem with radon.

Quick Overview of Radioactivity

We encounter the word radiation in a variety of different contexts every day. Radiation can refer to the microwaves we use to reheat our dinner, the treatment used for certain types of cancer, and the constant bodily barrage we experience from any number of sources at any given moment (e.g., ultraviolet sunlight, X-rays from dental screening, cosmic rays from air travel, geologic sources of radioactive decay, etc.) (Centers for Disease Control and Prevention, 2015). When looking at radioactivity, however, we concern ourselves specifically with those elements having large, unstable nuclei that spontaneously decay and emit certain particles (\(\alpha\), \(\beta\)) or radiation (\(\gamma\)) (Chang & Overby, 2019).

Radioactive Decay

An atom is composed of a central nucleus containing protons and neutrons. Surrounding the nucleus, in a cloud, are the negatively charged electrons, which are responsible for the chemical behavior of elements (e.g., reactivity, boiling point, etc.). Inside the nucleus, positively charged protons may be bound to one another and to aptly named neutrons—depending on the atomic number and isotope variety—via the nuclear strong force.

The strong force is one of the four fundamental forces of nature,\(^3\) and is an attractive force between nuclear particles over very short distances (e.g., approximately 4 proton diameters), regardless of electrostatic charge (“Nuclear properties,” n.d.). Across the span of a few protons, the strong force overcomes the electropositive repulsion protons exert on each other and binds them together. As the nucleus gets larger, though, the overall positive repulsion grows, leading to the tendency of large nuclei to become unstable\(^5\) and break down or separate over time. Neutrally charged neutrons serve to mediate the electrostatic repulsive effects between protons by acting as a buffer, and they can have a stabilizing effect on the nucleus—at least, up to a certain size (i.e., about equal numbers of protons and neutrons) (Matis, 2019).

Of interest to us is nuclear decay through the emission of an alpha particle—essentially a helium nucleus with no electrons.\(^6\) When a portion of the nucleus, consisting of two protons and two neutrons, is jettisoned, we call the cluster of nuclear material an alpha (\(\alpha\)) particle. An \(\alpha\)-particle is relatively large compared to other decay products, carries a +2 charge—due to the two protons and no balancing electrons—and has a high exit velocity from the nucleus, enabling it to travel up to distances of about 0.1 mm within the structure

---

1. Radon is chemically unreactive.
2. There are at least 37 known isotopes of radon, only four of which are naturally occurring: Rn-222, Rn-220, Rn-219, and Rn-218 (Haynes, 2015). The symbolic representation of \(^{222}_{86}\text{Rn}\) refers to 222 atomic mass units with an atomic number of 86 for the element radon; since all radon atoms have an atomic number of 86, we may also write Rn-222 to indicate the specific isotope variety. Half-life is the amount of time it takes for half of a sample to decay.
3. The atomic number is the number of protons an atom contains and defines the element (i.e., 1 is the element hydrogen). Isotopes are atoms of the same element with differing numbers of neutrons; for example, hydrogen may be one of three isotopes: protium (1 proton only), deuterium (1 proton with 1 neutron), or tritium (1 proton with 2 neutrons).
4. The other three are: electromagnetic (includes both electrostatic and magnetic), weak, and gravitational.
5. Stability of a nucleus refers to how tightly bound nucleons are as a function of how much energy (i.e., binding energy) is necessary to separate them (“Nuclear properties,” n.d.).
6. The bulk of Earth’s atmospheric helium—the sixth-most abundant gas at 0.0005% (Chang & Overby, 2019)—is He-4, produced by the alpha decay of radioactive elements.
of a mineral (Nesse, 2017). When an unstable element decays radioactively by shedding an alpha particle, it brings the ratio of protons to neutrons down, leading to greater nuclear stability (Matis, 2019).

Units of Radioactivity
When reading about radioactive decay, the units commonly used include the bequerel (Bq) and the curie (Ci), both of which describe the number of nuclear disintegrations per second: the Bq is equal to one disintegration per second, and the Ci equals $3.7 \times 10^{10}$ disintegrations per second (Faure, 1998). Regarding radon gas, concentrations are commonly reported in picocuries per liter (pCi/L), establishing an approximate unit for decay of about one radioactive atom every thirty seconds for each liter of air in a home.7 The application of these units is seen in the Environmental Protection Agency’s (2016) recommendation for homeowners to take mitigative action when radon gas concentrations exceed 4 pCi/L of air.8

Where does radon come from?
Origins
Radon originates in rocks and minerals that contain uranium. The average crustal abundance of uranium in the Earth is 1.8 parts per million (ppm) (Mason & More, 1982, as cited in Nesse, 2017), with typical specific rock concentrations of 0.75 ppm for basalt, 3 ppm for granite, and 3.7 ppm for shale (Faure, 1998). Uranium is an incompatible trace element in minerals, meaning it does not substitute readily (due to its large size) within mineral structures, and this concentrates its presence in the melts during partial melting of basalts (Winter, 2010), explaining why it may have a 4x greater concentration in granitic rocks.

Being a large element consisting of 92 protons and 143 (U-235) or 146 (U-238) neutrons, uranium is radioactive, and average outdoor concentration of radon (at about 0.4 pCi/L; Environmental Protection Agency, 2016) accumulated in the atmosphere by this process.

Decay of Radon
Radon gas itself is unstable and further decays into radioactive progeny,9 such as polonium, which is a highly toxic metal (Stwertka, 2002). It is the emission of alpha radiation and the buildup of polonium in lung tissues that seems to be the more immediate carcinogenic concern than the radon par-ent (Institute of Medicine, 1995; National Research Council, 1988). Radon and polonium may attach to dust particles and be inhaled in this way too, in addition to the inhalation of free elemental forms directly from the air (Institute of Medicine, 1995).

How does radon enter the home?
Since radon is a gas it may enter the home via diffusion or by pressure gradients (Dixon, 2005; Bailey et al., 2002),
Comments on proposed rule: Modernization of Property Disclosures for Mining Registrants

Comments on the U.S. Security and Exchange Commission's (SEC's) proposal are available at https://www.sec.gov/comments/s7-10-16/s71016.htm

John Berry, CPG-04032, Editor
Want to purchase minerals and other oil/gas interests.
Send details to:
P.O. Box 13557, Denver, CO 80201.

PROFESSIONAL SERVICES DIRECTORY

This service is open to AIPG Members as well as non-members. The Professional Services Directory is a one year listing offering experience and expertise in all phases of geology. Prepayment required. Advertising rates are based on a 3 3/8” x 1 3/4” space.

ONE YEAR LISTING FOR ONLY:
- AIPG Member $400.00
- Non-Member $500.00

Space can be increased vertically by doubling or tripling the size and also the rate.

In Memoriam
Richard L. Nielsen
CPG-11459
Member Since 2004
Passed on December 8, 2019
Golden, Colorado
and because it dissolves in water, radon may also be carried in from groundwater sources and wells. The type of rock and soil a home is constructed on determines how much radon may be present in a specific location, as well as how easily the gas is able to move: gravels and sandy soils, with their large pore spaces, facilitate the movement of radon much better than do clays (Bailey et al., 2002). Radon within soil moves from higher pressures outside the home through concrete floors, walls, and along service pipe openings, into the lower pressures inside (Environmental Protection Agency, 2016). The lower pressure inside a home is caused primarily by heating, and therefore, pressure differences are typically greatest at night and in certain seasons (e.g., winters) (Dixon, 2005).

Radon that enters the home in water may be released into the air during evaporation when the water is expelled from faucets and showerheads (Keith et al., 2012). The composition of the reservoir rock or soil from which groundwater is drawn matters, with higher radon concentrations associated with granitic rocks and their derivative soils (Institute of Medicine, 1995). Radon gets trapped in the home and the amount of gas can build to dangerous levels. Concentrations of radon tend to be higher on lower levels of a home, particularly in basements, as these areas are in direct contact with the ground or are closest to it.

Health Effects of Radon Exposure

Radon gas is the second leading cause of lung cancer, following cigarette smoke in the general population (Centers for Disease Control and Prevention, 2019b; Kang, Seo, & Jin, 2019; Seltenrich, 2019). As a public health concern, radon exposure is a known carcinogen, responsible for 21,000 deaths a year in the United States, which equates to 10% of total lung cancer deaths (CDC, 2019b; Larsson, 2014). At even moderate concentrations, radon and other radioactive elements pose dangers to human health. Alpha particles carry a positive charge, and resultingy, can transfer energy through direct contact with atoms or molecules in other materials, leading to ionization (i.e., taking on a positive or negative charge), excited energy states, and cellular damage (Bailey et al., 2002). When radon atoms undergo decay, electrically charged particles float into the air and are inhaled into the tracheobronchial tree and lungs. The tracheobronchial tree involves the lower respiratory tract (trachea, bronchi, and bronchioles) where gas exchange occurs. Once you breathe in the radon gas, the radioactive particles enter the respiratory tract and accumulate. Cellular DNA damage is confined to the epithelial tissues in the respiratory tract. Health issues do not initially present but take several years for any signs and symptoms of lung cancer to appear including shortness of breath, coughing, and bloody sputum (CDC, 2019b; EPA, 2016).

Even a single alpha particle poses risk for genetic mutation and potential cancerous growth. The chances of developing lung cancer from exposure to radon gas depend on various factors: the level of radon gas in your home, including the living space in which you spend the majority of your time, how much time you spend in your home, if you are a smoker or exposed to cigarette smoke, and whether you burn wood or coal to heat your home (CDC, 2019b; EPA, 2016). All homes are at risk for radon gas accumulation, including new construction and older homes, well-sealed homes and homes with cracks and gaps in the foundation, as well as homes with or without basements (EPA, 2016). Unfortunately, even with the capability of lowering the level of radon gas in your home, it is still undetermined whether radon gas inhalation causes other health effects (Kang, Seo, & Jin, 2019). The lungs are closely connected to other organs of the body via blood supply in the capillaries where gas exchange occurs. Radon gas easily dissolves into the blood stream and circulates, giving opportunity for cancerous mutations to spread and proliferate in the liver, brain, bones, and kidneys. According to Turner et al. (as cited in Kang et al., 2019), a Cancer Prevention Study II trial was conducted to determine health effects of radon exposure to patients with Chronic Obstructive Pulmonary Disease (COPD) -- a chronic lung disease causing inflammation, narrowing of the bronchial airways, and increased mucous build up -- and found a significant association with radon exposure and COPD mortality (Mayo Clinic, 2010). Some studies conducted support the theory that radon gas levels in the body can be a contributing factor for other cancers such as leukemia, basal cell skin cancer, and melanoma (Schwartz & Klug, 2016; Vienneau et al., 2017).

How do we test for the presence of radon?

Radon cancer associated deaths are preventable when there are protective measures in place. It is recommended by the U.S. Surgeon General that all homes be tested for radon gas (CDC, 2019b). According to the EPA, on average, “nearly 1 out of every 15 homes in the U.S. is estimated to have elevated radon levels” (EPA, 2016, p. 4). Indoor levels of radon gas are a modifiable risk factor, which means that with proper control strategies, radon levels can be reduced to safer levels. Radon levels vary from house to house and may even differ from room to room in the same house. Variables to consider when figuring radon gas levels include soil around the home, house materials, and how well or how often the home is ventilated (Si-Heon, Sang-Baek, Cheol-Min, Changsoo, & Dae Ryong, 2018).

As previously mentioned, radon can also be found in ground water resources, but there is a lack of empirical evidence regarding the dangers of consumption of radon. According to the WHO (2016), there is no strong evidence linking the ingestion of water containing radon with health issues, such as stomach cancers. Although there is risk of exposure to radon through water, the risk of exposure through soil is much more concerning. One way to protect yourself from water radon levels is to get your private wells tested and have the water supply treated prior to it entering your home (American Cancer Society, 2019).

Home Testing

Radon testing is an easy way to determine how much radon gas is leaking into your home. There are cost effective home testing kits you can purchase, or you can hire a certified radon testing professional. A short-term test is completed in two to 90 days. Radon levels fluctuate with time of day and vary with seasons, so short-term testing is not ideal to determine yearly average test results. If a short-term test is implemented, it is recommended that a follow up short-term test be done to evaluate if radon gas levels are indeed elevated (EPA, 2016). The homeowner will want to ensure that all doors and windows are closed at least 12 hours prior to testing for most accurate radon gas readings (EPA). Long-term radon testing is done in the home over more than 90 days and will provide a more accurate account of average radon air levels throughout the
Mount Rainier
(Washington):
a volcanic landscape overflowing with geomorphological wonders!

Isaac E. Pope, SA-9950

At nearly 4400 meters in elevation, Mount Rainier in Washington State is the tallest and iciest quaternary volcano of the Cascade Range. Although Mount Rainier has gained an ominous reputation as one of the world’s potentially most dangerous volcanoes, almost two million tourists annually visit it to enjoy its majestic heights. As a stately member of the Cascade Volcanic Arc, Mount Rainier has an extensive history of volcanism and the ensuing mass wasting events that have dominated the region since the late Pleistocene. These volcanic events have alternated between emplacement of andesitic lava flows and eruption of tephra deposits and pyroclastic flows. Occasionally, catastrophic collapses of the dome during eruptions transformed into prodigious lahars that decimated drainages all the way to Puget Sound itself. In one such case, extensive hydrothermal alteration in the volcanic cone gradually transformed the silicic minerals into a more and more unstable mass of clay, until one day a phreatomagmatic eruption triggered one of the greatest mass wasting events of Mount Rainier: the Osceola Mudflow. As the cone collapsed, this flow surged to Puget Sound, depositing in its wake a veneer of clay and other aggregate up to 20 meters in depth over an area of nearly 550 square kilometers. Rapid melting of glaciers during these volcanic episodes have induced comparatively smaller inundations. With eruptions as recently as the nineteenth century, the certainty of future eruptions threatens over 150,000 individuals who live on these ancient lahar deposits. However, it is this intricately tumultuous history that has made Mount Rainier such a gem for modern geoscience, as a place to study arc magmatism, extrusive activity, glaciation and the resulting lahars. Recently I embarked on an exploration to investigate this history for myself.

My adventure began early one September morning as I proceeded into Washington’s fog-enshrouded High Cascades, traversing great valleys and circumnavigating the eastward dipping strata of the Cascade Volcanic Arc until arriving at the foot of Mount Rainier. With a predicted 40 percent chance of rain and clouds already looming in the distance, I proceeded towards the ranger station at Longmire to meet Taylor Kenyon, MS, a recent (2016) graduate of University of Washington and the first Imminent Threats Technician at Mount Rainier National Park. After solidifying our plans for the day, we drove up the flanks of the cone. As we ascended these flanks it became increasingly difficult to concede that Mount Rainier was only a late comer to the volcanism and plutonism that has dominated this region since the Oligocene. Composed primarily of pyroclastic deposits intercalated with more voluminous andesitic flows, Mount Rainier has rarely had such copious plinian eruptions as has its infamous neighbor Mount St. Helens, although Rainier’s slopes have been dusted occasionally by tephra deposits from Mount St. Helens. With a bedrock of Miocene Snoqualmie Granodiorite and older volcaniclastic strata underlying it, Mount Rainier stands alone as a truly remarkable composite cone with a history directly related to, yet distinct from, that which preceded it.

Once we arrived at the appropriately named Skyline Trail, I accompanied Taylor as he examined the automated cameras that are used to document the movements of the Nisqually Glacier on Mount Rainier’s southwestern flank. To get there, however, would be a painful trek – the trail rose along a grade exceeding twenty degrees. After a few rests, we arrived at a stunning view of Mount Rainier towering 3000 meters above us. As we examined the equipment at the first camera (Fig.1), we soon had a visitor begging for food – an obese Hoary Marmot

Figure 1 - Nisqually Glacier up-valley of the terminus on the southwestern flank of Mount Rainier. Unusually excessive ablation over the preceding years had caused substantial crevasses in the upper portion of the glacier. The automated camera visible in the foreground beyond the backpack provides the scale.
Driving along a road constructed in the early 1930s as a section of a scenic drive about to become far more exciting to me. Returning to our vehicle for what was discussing glacier dynamics and the porting the hillside and causing major hundred meters, thereby no longer suppression. In the last few decades alone, the recent resurgence of glaciation during the ‘Little Ice Age’ of the last millennium. Since that time, Mount Rainier’s glaciers have continued in a dynamic recession. In the last few decades alone, the Nisqually Glacier has retreated several hundred meters, thereby no longer supporting the hillside and causing major sloughing.

After examining the equipment and discussing glacier dynamics and the surrounding granodioritic bedrock, we returned to our vehicle for what was about to become far more exciting to me. Driving along a road constructed in the early 1930s as a section of a scenic drive proposed to circumnavigate the entire subalpine region of Mount Rainier, we toured the wonders of this forgotten portion of the park. At the end of our fifteen-kilometer drive, Taylor asked which hike I would like to examine. I replied, “Whatever you find the most interesting, but personally I would enjoy seeing those recent glacial outburst flood deposits.” These gravels were deposited just a month beforehand when, on August 7, a jökulhlaup inundated the Nisqually River drainage. Jökulhlaups are caused by an influx of meltwater that overwhelms the internal storage of the glacier, causing weak portions to fail and to discharge a prodigious torrent into the river drainage below. Although they were first extensively studied in Iceland, relatively little is known about the sedimentological and geomorphological nature of these outbursts in an alpine glacier setting. Taylor gladly drove us to the desired trail, which was closed to the public after the flooding: he had been studying the deposits there and was also interested in seeing them again.

We arrived at the scene, entering a mature forest that quickly thinned as we approached the floodplain. In one shallow channel we found a surviving tree muddied by a “splash mark” from the inundation depositing fine sediment as it circumvented the tree. Interestingly, the highest deposited mud on the upriver side was nearly two-thirds of a meter above that on the downstream side, recording the tremendous force that the viscous flow unleashed on this silent bystander. We also documented some minor depositional terraces composed of laminated coarse sand deposited during the diminishing stages of the flow. The real spectacle was the tremendous boulder deposits, which terminate in lobes of boulders that document the extent of the currents flowing at the highest velocities and carrying the greatest sediment load. We discussed the dynamics of the flow and the previous condition of the flood plain, including that of a nearly three-meter trench that was once occupied by the river but is now filled with sediment. Finally, however, we found a prime area in which to view the sedimentation – a prodigious gully formed as the diminishing flow transacted its own deposits and cut into the underlying stratum (Fig. 3). Here the deposit of glacial outburst flood measured nearly two meters thick and was characterized by matrix-supported reverse grading of poorly-sorted imbricated siliciclastics (andesitic lithic clasts being the major constituent), as is common with these deposits. Crevices between boulders had become sediment traps for coarse sands. Here cross-stratification was common throughout, particularly where light clay laminae acted as “marker beds” (Fig. 4).

We also examined the contact between the glacial outburst deposits and the underlying stratum, demonstrating the truth of Taylor’s assertion that mapping these deposits “can be a messy job.” Once we pried ourselves from these fascinating deposits, we observed two examples of subsurface flow; one of which utilized the large voids between boulders at the surface to access an underground path, while the other was filtered through coarse sands. Both were branches of the same tributary that fed into, but were otherwise unassociated with, the glacially-fed stream, as was evidenced from the lack of rock flour and similar glacier debris in this minor tributary.

Our day soon ended, and with that came our parting. I had enjoyed a marvelous day of geologic study, and Taylor had as well; I also had much to consider. In more than a half-century of extensive research, geologists had painstakingly unraveled the history of Mount Rainier, a history characterized by great volcanism, monumental glaciation, and unparalleled mass wasting, and yet so much is to be learned of even the seemingly most elementary of these processes, both here at Mount Rainier and at volcanoes around the world. Mount Rainier provides a fascinating arena for both research and education, having all major domains of geology represented.

Figure 2 - Taylor (leading) and author (following) hike southerly along the edge of the left lateral Little Ice Age moraine near the Moraine Trail. During the Little Ice Age, the valley in this area harbored a more robust Nisqually Glacier, whose dramatic retreat caused certain areas of the trail to be destroyed as the moraine sloughs into the stream. The Tatoosh Mountains of the Snoqualmie Granodiorite are visible in the distance.

(Marmota caligata of Order Rodentia). This critter was so tame that it seemed possible to pick him up as a pet, but Taylor would have none of that. Much to the chagrin of those watching us from a nearby knoll, he shooed the marmot as far away as possible (which was only a few meters – this marmot was an annoying creature who waited to see if we would change our minds!). After this bestial interruption and several discussions on the local geology, we retraced our steps much more easily until diverting to the Moraine Trail to examine a second camera stationed downstream of the glacier’s present terminus (Fig. 2).

Extensive lateral moraines and trimlines in the area testify to the geologically recent resurgence of glaciation during the ‘Little Ice Age’ of the last millennium. Since that time, Mount Rainier’s glaciers have continued in a dynamic recession. In the last few decades alone, the Nisqually Glacier has retreated several hundred meters, thereby no longer supporting the hillside and causing major sloughing.

After examining the equipment and discussing glacier dynamics and the surrounding granodioritic bedrock, we returned to our vehicle for what was about to become far more exciting to me. Driving along a road constructed in the early 1930s as a section of a scenic drive proposed to circumnavigate the entire subalpine region of Mount Rainier, we toured the wonders of this forgotten portion of the park. At the end of our fifteen-kilometer drive, Taylor asked which hike I would like to examine. I replied, “Whatever you find the most interesting, but personally I would enjoy seeing those recent glacial outburst flood deposits.” These gravels were deposited just a month beforehand when, on August 7, a jökulhlaup inundated the Nisqually River drainage. Jökulhlaups are caused by an influx of meltwater that overwhelms the internal storage of the glacier, causing weak portions to fail and to discharge a prodigious torrent into the river drainage below. Although they were first extensively studied in Iceland, relatively little is known about the sedimentological and geomorphological nature of these outbursts in an alpine glacier setting. Taylor gladly drove us to the desired trail, which was closed to the public after the flooding: he had been studying the deposits there and was also interested in seeing them again.

We arrived at the scene, entering a mature forest that quickly thinned as we approached the floodplain. In one shallow channel we found a surviving tree muddied by a "splash mark" from the inundation depositing fine sediment as it circumvented the tree. Interestingly,
Figure 3 - A large trench nearly three meters deep exposes the jökulhlaup deposits of August 7, 2019 and underlying stratum. Note the magnitude of clasts deposited in the poorly sorted sediments and the height of the mudline on the tree in the background above the researchers Taylor Kenyon and the author in the channel.

(igneous petrology, glaciology, sedimentology, seismology, etc.). I am greatly looking forward to continuing my study of such a remarkable geologic wonder!

Acknowledgements
I am grateful to Scott Beason and Taylor Kenyon of Mount Rainier National Park for their time and assistance and especially to Taylor for entertaining me for the day. I also thank Prof. Pat Pringle (Centralia College) for his insightful review and Dr. Marc Hendrix (University of Montana) for encouraging me to submit this essay.

About the Author
Isaac Pope is a young undergraduate student with an insatiable fascination of geoscience, accumulating a considerable reading list of graduate-level texts since the age of fourteen. Not only has he conducted much university-level research on both geological and mathematical topics, but he is also greatly interested in education stemming from his desire to share the wonder of science and mathematics with others.

Figure 4 - Trough-shaped, cross-stratified volcanogenic sand that was deposited in sediment traps among boulders during the jökulhlaup of August 7, 2019. Note the striking clay-silt laminae indicated by the arrow in B.
year compared to a short-term radon test. If a short-term test was completed and results indicated 4 pCi/L or higher, a long-term test is warranted for better analysis of year-round radon levels (EPA).

**How do we mitigate the radon hazard?**

If radon testing results reveal an excess of 4 pCi/L, a certified mitigation installer should be contacted to install a passive ventilation system and fan, which vents radon from beneath your home to the outside (EPA, 2016; Seltenrich, 2019). It is also recommended to seal up any cracks or gaps in the foundation of your home to prevent air leakage from the soil below (EPA, 2016).

Further recommendations include retesting radon levels in your home every 2 years after mitigation system installation. Smoking cessation is also encouraged. Smoking indoors or breathing in second-hand smoke further increases the risk of lung cancer when exposed to radon too. The EPA reports that radon and smoke inhalation have a synergistic effect, increasing the risk of mortality from 7.3 people in 1000 nonsmokers to 62 out of 1000 for smokers dying of lung cancer (2016, para. 5). When weather permits, open windows and screen doors to ventilate the home (Larsson, 2014).

**Summary**

Radon gas is a radioactive indoor air pollutant that poses a health concern for society. Detection of radon gas through home testing is easy and mitigation system installation is a viable way of reducing the level of radon concentration in the home, thus reducing associated health risks.

**References**


Undergraduate students from Michigan Technological University’s Mining Innovations Enterprise are supporting a NASA Early Stage Innovation grant with researching how to mine gypsum on Mars, with the end goal of extracting the mineral’s bound water. The flow-chart for this process is shown in Fig. 1. Gypsum is twenty percent water by weight, providing a potential source of pure water that can be extracted. The extracted water can be used for rocket propellant and life support when the first humans arrive on Mars. This decreases the demand for transporting mass quantities of rocket propellant and pure water from Earth. The gypsum will be broken down and collected using a system that includes a water jet (Fig. 2), a suction system, a settlement tank to separate liquid water from gypsum particles, and a pressurized enclosure. This research is being done in partnership with a physics graduate student. The gypsum will proceed from the suction system into a calcining reactor (Fig. 3). The calcining reactor heats the gypsum slurry coming from the disaggregation and suction system via the settlement tank in batches, and stirs it with an agitator. Hot air cycles through the closed system, picking up water vapor and transporting it to a condenser where the liquid water is collected. The anhydrous heated form of gypsum—known as anhydrite—is dumped into a lower portion of the reactor where it will help heat the cycling air and speed up the process for the next slurry batch (Loop on Fig. 1). When the next batch is added, the anhydrite will be dumped as a waste salt. Experimental trials are being conducted using a one-third scale prototype of the reactor built by a 2018 mechanical engineering senior design team. The reactor is currently undergoing modification to improve the agitator stabilization and optimize the data output.

I am leading research in identifying and locating gypsum on Martian terrain. There are currently two working theories on the geophysical methods that can be utilized in such conditions: electrical resistivity and ground penetrating radar (GPR). Another possibility is the IR signature.

The electrical engineering and control system team is focusing on investigat-
ing electric resistivity as a method of identifying gypsum. They are helping to build a terrameter that can be used for lab testing on both sabkha and deep basin gypsum, and which can be modified for use on our field test rover. The terrameter will input a current through two electrodes and read the voltage difference from the other two electrodes, resulting in an output of ground resistance. These lab tests will use this Wenner array setup on gypsum rock at a variety of spacings to determine the range of resistivity values in gypsum. Once the lab tests are completed, the electrode arrays will be studied further to determine the optimal array.

The second method being researched is ground penetrating radar (GPR). The GPR can be used to locate the area and depth of gypsum once it is identified using electric resistivity. The antennas used will be very small—as the water jetting method can only complete surface mining to a depth limited by the reach of the robotic arm. Michigan Technological University’s archaeology department has agreed to work with us on field testing with their GPR. Field tests will help to analyze the antennas needed to reach our optimal depth penetration of about two meters. The tests will ideally include use of the previously built field test rover that has a payload bay in the center where the GPR could be placed for field tests. The geophysical research of gypsum location is in its infancy for the Mining Innovations Enterprise, but physical testing of these methods is soon to occur.

Continued from p. 33

Pictured left: The wall at a quarry into the Waccamaw Formation, which represents the last period of warmth before Pleistocene glaciations dropped the sea level. Over a hundred species of mollusks, foraminifera, sponges, corals, and vertebrates are known from this site alone.

complex. It has inspired us to travel and explore, given us the excuse to do so, and taught us the skills we need to explore our world in a very real sense. It also lead to a major shift in the way we think about geology as teachers, changing the way we teach in the classroom and enabling us to teach outside of the classroom as well. We hope to use what we have learned in the classroom and field as Ph.D. Paleontologists to educate and inspire our students and readers for the rest of our careers.

About the Authors

David Peterman is a Ph.D. candidate in Wright State University’s Environmental Sciences Ph.D. program. He had previously earned a BS and an MS from WSU’s Earth and Environmental Sciences department. He studies the quantitative paleobiology of octococchleate cephalopods, focusing on virtual reconstruction and biomechanics. Fall semester David is teaching Paleobiology at Wright State.

Ryan Shell is a Ph.D. candidate in Wright State University’s Environmental Sciences Ph.D. program as well. He earned a BS in Geology from the University of Arkansas and began his work in Ohio by beginning an MS in Earth and Environmental Sciences with Wright State before moving his projects into the Ph.D. program. He studies the biodiversity, biogeography, and paleoecology of marine vertebrates during the early Permian Period, specializing in sharks. In the Fall semester Ryan is teaching the Paleobiology of Dinosaurs at Wright State.
Using Taylor Series to Assess Goodness of Groundwater Models

Authors
Grubaugh, K.E. - Georgia Institute of Technology, Wilkins, B.D. - Massachusetts Institute of Technology, Hromadka II, T.V.3 (AS-0020) - United States Military Academy

Abstract
A problem of high interest to practitioners and researchers of groundwater flow problems is the goodness of outcomes produced from computational models. With domain-type computational models in frequent use - for example, those involving finite element, finite difference, finite volume, or other techniques - the topic of discretization effects is of high interest in assessing the goodness in model results. In this paper, we investigate the use of Taylor Series approximation to demonstrate the anticipated effectiveness of levels of discretization. We show how Taylor Series can be effectively used to evaluate anticipated departure between computational outcomes and the underlying analytic solution to the governing mathematical system of equations.

Keywords - Taylor Series, Groundwater Models, Complex Variable Boundary Element Method

Introduction
The Complex Variable Boundary Element Method (CVBEM) motivated this work by way of using approximations to solve complex variable equations, such as a complex variable Taylor Series. The CVBEM was introduced in Hromadka and Guymon (1984) and has been the subject of numerous investigations and applications throughout several facets of engineering. Among common applications of the CVBEM in engineering are fluid flow, hydraulics, and heat transfer. In 2002, Hromadka extended the CVBEM to three-dimensional (3D) domains of irregular geometry to accommodate practical problems that commonly occur in geoscience topics. For example, a 2017 study examines unsteady groundwater mounding problems (Wilkins, et al.) and Johnson et al. (2016) studied application in freezing and thawing soils in algid climates. Other applications are reported in the literature. More recently, Hromadka and Whitley (2014) provided a development of multi-dimensional applications using two-dimensional complex variable basis functions within the usual CVBEM framework. In tandem with this on-going research is the evolution of the visual computational error measure called the Approximate Boundary Method (ABM). First introduced in “CVBEM Error Reduction Using the Approximate Boundary Method” (Wood et al., 1993), the new techniques discussed here refine the accuracy achieved by the ABM by visually displaying the computational errors in position versus the number of nodes used in the approximation.

The CVBEM encompasses considerations of other variants of the general procedure such as the Method of Fundamental Solutions, or Generalized Fourier Series, and so forth. It is noted that the CVBEM is based upon use of complex variable analytic functions as basis functions. Since the modeling basis functions are analytic, linear combinations are also analytic functions on a properly defined, simply connected domain, D, enclosed by a simple closed boundary, B. A real function that satisfies the Laplace equation is said to be “harmonic”, and there exists an analytic function whose real part is the considered harmonic function. The Cauchy-Riemann equations state that the imaginary function portion of an analytic function is known within an integration constant, and can be determined from the real part of the analytic function. Therefore, both real and imaginary parts of the analytic function satisfy the Laplace equation and are harmonic functions. Additionally, being conjugate functions, level curves of the real part are orthogonal to level curves of the imaginary part, resulting in the well-known graphical display of “flow nets” that apply to numerous applications in science, mathematics, engineering and related fields. Such properties do not similarly exist for real value approximation functions and associated computational methods.

A Taylor Series expansion is a method used to evaluate a given function with infinitely many terms, as shown below. In engineering, these expansions are typically used to approximate functions by using only a small number of terms for a value when used to evaluate the function, ultimately saving time and resources for near-exact solutions. The successive derivatives, one of the unique features of a Taylor Series, are seen in the numerator of each term of the expression. In the complex domain, any function that is analytic at a given point, say z, will have a Taylor Series about that point. Therefore, it follows that the series will converge on f(z) at each point z in

1. For discussion of a particular (but very important) case, see https://en.wikipedia.org/wiki/Basis_(linear_algebra)
the finite plane. Whenever a finite number of terms is used, it is considered a Taylor Series approximation. Several studies, including this one, focus on how efficient these approximations are for evaluating specific problems. The general case for the Taylor Series is

$$f(z) = \sum_{n=0}^{\infty} \frac{f^n(z_0)}{n!}(z - z_0)^n$$

In this work, the CVBEM approximation technique will be formulated using complex polynomial (monomials) basis functions instead of the usual products of complex polynomials with complex logarithmic functions. The resulting formulation has direct ties with the Taylor Series formulation for analytic functions. Using flow nets developed from the CVBEM approximations, the modeling effort focuses on increasing computational accuracy until the CVBEM model flow net arrives at an acceptable geometric approximation to the problem boundary conditions. At this stage of model development, Taylor Series can be used to examine the precision of computations based upon the more general finite-difference, finite element, and finite volume type approaches. In this way, one can assess the precision of the domain model under consideration, and evaluate the departure between the domain model computational outcome and the underlying solution to the governing mathematical system of equations. Such assessment provides more information useful towards discretization density determination of modeling nodes and cells while possibly reducing computational burden.

**Real Variable Taylor Series Animations**

The Taylor Series corresponding to a function requires that the target function have derivatives of all orders. This requirement is similarly found with complex variable functions that are analytic. Both the real variable version and the complex variable version of Taylor Series are of similar construction, resulting in a sequence of function terms that relate the various orders of derivatives with monomial terms and associated constant coefficients. This sequence of terms is summed to form a series, where the first n terms is called the nth partial sum. Because the Taylor Series involves an infinite number of terms, only the initial portion of the series is used in approximation problems. How these “partial sums” behave is demonstrated by the example case studies presented and corresponding graphics. Intuitively, increases in the partial sum number of terms generally correspond to improved computational accuracy. Of special note is that the Taylor Series includes an error bound term that provides an upper bound estimate to computational error associated with a target partial sum. Of value to the computational modeling is that Taylor Series can be used as a case study to test the desired computational model and then use the resulting Taylor Series solutions and computational error for the known problem solution to assess the computational error associated with the target computational model as applied to the test problem. In this way, the Taylor Series can be used as a test case to assess the goodness of the target computational model, including issues such as modeling nodal point spacing and density, and so forth.

The sensitivity of the approximation to the number of terms, n, is demonstrated by the animations provided below. In the key to each graph, the numerical value is representative of the number of terms used in the evaluation. For instance, T0 is simply the function solved with $n = 0$, where T10 is the Taylor Series expansion to the 10th term. Figure 1 demonstrates the effectiveness of a partial sum on a function with a singularity at point $x = 1$.

In the following two figures, pay special attention to the fit of each line in respect to how many terms the line represents. Notice how the T0 is simply a line that only fits the specific value, and with the addition of each term the line becomes more closely related to the desired function. The T10 line stays along the original function line for the largest range of values, as anticipated.

In Figure 2, an example without a singularity, the difference is far more distinguished. Just as before, notice how the addition of terms makes the partial sum approximation more closely resemble the desired function.

**Examining the Complex Variable Taylor Series Term**

In the complex domain, a Taylor Series is a sum of complex monomials. Each complex monomial is an analytic function and is composed of its real part and corresponding imaginary part, with both parts being harmonic, two-dimensional real functions that satisfy the Laplace equation. Furthermore, these two parts satisfy the Cauchy-Riemann equations and therefore are complex conjugate functions where either part is derivable from the other. These can be visualized using flow nets. To demonstrate the flow nets for such complex monomials, the following depictions are presented for the first several monomial terms.

![Figure 1](image_url) - A depiction of a function $f(x) = \frac{\sin(x)}{(x - 1)}$ with a singularity at $x = 1$ evaluated at $x = 0.5$ (left) and $x = 1.5$ (right).
It is noteworthy that these individual flow net diagrams can be combined via the Taylor Series formulation as in a partial sum construction and plotted, resulting in a flow net corresponding to the partial sum. Shown in the following is the evolution of the partial sum flow net with increasing numbers of terms in the Series for the classic complex analytic function $e^z$. It is noted that these partial sum flow net visualizations are combinations of the individual complex monomial flow nets, weighted according to the complex derivative term values evaluated at the selected expansion point.

In the Taylor Series formulation, we determine the entire spectrum of complex variable derivatives and then evaluate at a selected expansion point, $Z_0$, that is held constant for the evaluation of the entire series. Of course, the entire spectrum of terms involving complex derivatives is evaluated at the chosen expansion point. The complex monomials that are also evaluated with respect to the chosen expansion point, $Z_0$, depend on the chosen expansion point location.

Figure 3 demonstrates the flow net for the exact solution. We present this to show what, in theory, the Taylor Series partial sum approximation flow net should look like as well once the approximation includes a sufficient number of terms. The series of four flow nets in the figure below demonstrates how quickly the addition of terms can model a complex example of the Taylor Series partial sum approximation. With only four terms, the graphic is nearly identical to the exact solution.

When comparing the flow net for four terms (the bottom right portion of Figure 4) to the flow net for ten terms (Figure 5) on page 60, it becomes apparent that there is a diminishing return beyond the fourth term in this instance.

The computational power required to solve a Taylor Series approximation is much less than that needed to find an exact solution. Some complex problems would require exact solutions that take hours or even days for a machine to solve, when a Taylor Series approximation to the fourth term, for example, is much more rapid. The saved computing time translates to both monetary savings and the creation of potential to address other problems.

**Suggested Future Work**

There are several key topics that need additional research. For example, multiple dimension Taylor Series would be important to apply in order to identify detailed aspects that require further work to resolve. Additionally, inclusion of the time derivative in a Taylor Series expansion may help improve upon the research. Another step towards proper development and application of such models is to apply all coefficients from a complete Taylor Series at a single expansion point. Observing how the total function performs with such information is still under investigation. Other topics are readily available for further research as well.

**Conclusions**

It is readily noticed that in order to develop the relevant Taylor Series partial sums that the solution to the governing equations must be known. However, using the graphical visualization of the
partial sum, estimates of these derivative terms at the selected expansion point can be developed by “fitting” the approximation flow net boundary iso-contours to the known problem boundary conditions iso-contour. This is a procedure called the “approximate boundary” fitting to the true problem boundary and involves a graphical visualization of computational error. The measure of “goodness of fit” between the complex approximation (partial sum) and the problem solution is the “goodness of fit” between the partial sum flow net and the problem boundary conditions.

The ability to use methods such as this one will allow use of non-standard modeling methods to determine more accurate approximations in problems dealing with geoscience topics such as groundwater flow estimates.

**Acknowledgements**

The authors would like to thank Dr. Theodore Hromadka II of the United States Military Academy at West Point, Department of Mathematical Sciences.
for his enthusiastic advising of the project and funding the work through his business, Hromadka & Associates.

References


The AAG Annual Meeting is an interdisciplinary forum where thought leaders and experts from geography — and its allied disciplines — intersect to build new partnerships and collaborations.

The conference will feature more than 6,000 presentations, posters, workshops, and field trips. Network and exchange ideas with more than 8,000 local and international colleagues. Foster new partnerships. Discover topical publications. Interact with state-of-the-art technologies.

annualmeeting.aag.org