# Critical Experiences for Field Geologists: Emergent Themes in Interest Development

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## ABSTRACT

Geoscience education researchers are working to understand how we can most effectively increase our overall geoscience workforce capacity. The present study employed an inductive approach to explore the critical experiences that led to the persistence of successful field geologists in this STEM field. Interviews with 29 professional field geologists and 8 upper level undergraduates were analyzed to identify emergent themes. Three overarching themes emerged: Academic Experiences, Connections with People, and Engagement with Earth. Academic experiences, such as introductory courses and field trips, were commonly mentioned as being significant in recruitment. Relationships with people, such as professors and family members, provided encouragement for and exposure to geology-related activities. Participants provided detailed description of the regional geology where they grew up and the geology of locales from family trips as experiences with Earth influenced their interest in geology. The results of this study validate past studies of recruitment and retention of geoscientists, particularly in the influence of academic experiences on interest in geology. However, the abundance of themes related to the role of family, engagement in outdoor recreation, and personal experiences with local geology underscores the importance of informal science experiences for fostering choice and participation in field geology careers. Future models of retention and recruitment for the geosciences could benefit from emphasizing familial relationships and informal science experiences.
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*Key words*: recruitment, informal science, STEM pipeline

## INTRODUCTION

In the United States, the geoscience community has sought successful strategies for recruiting and retaining geoscientists for the past decade (Brock et al., 2006; Huntoon and Lane, 2007; Levine et al., 2007; Baber et al., 2010).This area of research has garnered attention from researchers due to three key concerns: (1) geoscience industry leaders have identified an impending workforce crisis as a result of baby boomers nearing retirement (Feiss, 2008; Groat, 2008; Karsten and Patino, 2008; Powers, 2008; Summa and Loudin, 2008); (2) declining enrollment in geoscience departments coupled with the impact of the economic downturn on colleges and universities across the nation has positioned geosciences as ready targets for cuts (Gonzales et al., 2009; Gonzales and Keane, 2011); (3) our nation's diversity is not reflected in the geoscience community, as it is still a field dominated by white males (Huntoon and Lane, 2007).

A high job growth rate for the geosciences presents an opportunity for the geoscience community to promote careers and readily employ graduates from geoscience programs. The U.S. Department of Labor projects that the geosciences are expected to have a 21% job growth rate between 2010 and 2020, well above the average job growth rate of 14% (United States Department of Labor, 2012). Many of these jobs are in government and industry and the entry-level education is a bachelor's degree. A close examination of geoscience degrees awarded in the U.S. helps to illuminate the role of tertiary education in the production of American geoscientists. Huntoon and Lane (2007) explored data on U.S. STEM bachelors, masters, and Ph.D. degrees awarded over the past 40 years and found that geosciences have awarded the fewest degrees of all STEM disciplines. Currently, the U.S. is not producing the trained specialists required to fill the geoscience positions that are available and would benefit from more effective mechanisms for capacity building.

The analogy of a "pipeline" is commonly referenced as a conceptual model for studies investigating recruitment and retention of students across science, technology, engineering, and mathematics (STEM) disciplines (Blickenstaff, 2005; Burke and Mattis, 2007; Levine et al., 2007; Lent et al., 2008; Xu, 2008; Sanders, 2009). Individuals will either pass through the pipeline and be successfully retained in STEM careers or they will "leak" or "fall" out of the pipeline and pursue another career path. A pipeline model includes stages at which students may be recruited and/or retained. Many pipeline models use an academic framework, where the stages may include high school, community college, four-year college, and graduate school, for example. Studies employing these models identify programmatic features that recruit and retain geoscience majors.

Recruitment studies of undergraduates have demonstrated the influence of careers on choice and participation in geosciences (Table I). Hoisch and Bowie (2010) surveyed over 700 students in introductory geology classes dominated by lower-level nonmajors and 23 upper-level geology majors about their attitudes toward and perceptions of geology as a major. The participants' positive perceptions of geology included good job options and salary potential, as well as opportunities to work outdoors. In contrast, negative

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**TABLE I. Comparison of recruitment and retention studies of undergraduates and underrepresented groups. Previous studies are compared based on study focus, sample size, demographics, and methodology.**

| Study | Study Focus | Sample Size | Demographic | Methodology |
|---|---|---|---|---|
| **Hoisch and Bowie, 2010** | Recruitment of undergraduate majors | 23[1] | Undergraduate junior and senior geology majors, ethnicity unavailable | Open-ended survey[2] |
| **Houlton, 2010** | Recruitment of undergraduate majors | 17 | Undergraduate geoscience majors; ethnicity unavailable | Critical incident interviewing |
| **Levine et al., 2007** | Recruitment and retention in the geoscience pipeline | 14 | 11 researchers, 1 coordinator, 2 graduate students; 4 of 14 participants were from underrepresented groups | Critical incident interviewing |
| **Holmes and O'Connell, 2003** | Recruitment and retention of women in the geosciences | 91 | Undergraduates, graduates, postdocs, professors, and administrators[3]; ethnicity unavailable | Focus groups[2] |

[1]Sample information was only provided for the portion of the study involving majors.
[2]Methodological approaches for coding participant responses was not available.
[3]Demographics were not provided for the sample population.

perceptions of geology included low salary potential and low prestige relative to the other sciences (Hoisch and Bowie, 2010). Houlton (2010) interviewed 17 undergraduate geoscience majors using a critical incident (CI) technique, a method of data gathering in which subjects are asked to identify particularly influential experiences that impacted the subjects subsequent choices (Flanagan, 1954). From this study, Houlton (2010) identified six major pathway steps found to be integral for successful recruitment as a geoscience major: innate attributes, precollege CI, college CI, current/near-future goals, expected career attributes, and desired career choices. Houlton's model described two distinct populations of geoscience college students: "Natives" start college as geoscience majors with ambitions that are industry and government oriented, while "immigrants" switch into the geoscience major during college with career ambitions that are academic or research-oriented (Houlton, 2010).

Several of the studies on recruitment and retention in the geosciences have focused on broadening participation of underrepresented groups in the geosciences (Holmes and O'Connell, 2003; Brock et al., 2006; Huntoon and Lane, 2007; Levine et al., 2007) (Table I). Although these studies may not generalize to majority populations, this prior work comprises much of what is known about recruitment and retention. Brock et al. (2006) identified three factors that influenced minority recruitment and retention: (1) introductory level geoscience courses, (2) courses infused with place-based practices, and (3) extracurricular activities (Brock et al., 2006). Extracurricular activities may include participation in outdoor experiences and field trips (Levine et al., 2007). Holmes and O'Connell (2003) conducted focus groups with graduate students and faculty from geoscience departments across the U.S. to examine gender differences in recruitment and retention in the professoriate. Male and female participants identified the same five major influences that attracted them to the geosciences: undergraduate experiences, love of the outdoors or subject matter, family influences, miscellaneous, and/or K–12 teachers or experiences. The prior work on broadening participation demonstrates that in addition to academic influences, geologists are influenced by family and a love of the outdoors.

A recent report, *Preparing the Next Generation of Earth Scientists,* underscores the importance of understanding the range of experiences that attract and retain people in the geosciences (National Research Council, 2013). There are a variety of methodologies used to explore issues of recruitment and retention within STEM fields. Researchers examine the problem in many different ways, such as eliciting stories of experiences, identifying characteristics of STEM fields that foster interest or intimidation, modeling psychological and sociological factors that influence self-beliefs and motivations, and uncovering cultures and practices of individual STEM domains and subdomains. There will be some variables that are more critical than others for influencing recruitment and retention for particular groups. One step in this direction is to evaluate the experiences that contributed to successful engagement of the various subgroups of geologists, in this case field geologists.

The purpose of this study was to explore the experiences that fostered choice and participation in field geology careers. Prior studies reviewed above have used a deductive approach by specifying a theoretical model of recruitment and retention (e.g., the STEM pipeline) and employing complementary methodology to observe the components of their model (Trochim, 2006). The present study takes an inductive approach by applying grounded theory to identify emergent themes in participants' responses (Glaser and Strauss, 1967). Interviews were conducted with a convenience sample of 37 successfully pipelined field geologists during their participation in an unrelated expert–novice study (Libarkin et al., 2011; Petcovic et al., 2011; Hambrick et al., 2012). The participants' responses elucidate the self-identified experiences, both academic and nonacademic, that promoted their persistence in a field geology career path. The methodology of this study can potentially validate previous findings and contribute to a more complete model of fostering choice and participation in the geosciences.

## STUDY POPULATION AND SETTING

Twenty-nine field geologists and eight upper-level undergraduates were interviewed for this study and asked, "How did you get interested in geology?" The participants

**TABLE II. Demographic information for study participants.**

| Participant Attribute | Count, Mean, and/or Range |
|---|---|
| Gender | |
| Female | $n = 17$ |
| Male | $n = 20$ |
| Age | |
| Mean | 37.6 years (SD = 13.1 years) |
| Mode | 28 years |
| Range | 21–68 years |
| Ethnicity | |
| White | $n = 29$ |
| Hispanic | $n = 1$ |
| Hispanic/White | $n = 1$ |
| American Indian/White | $n = 2$ |
| Other | $n = 3$ (Self-identified specifically as Nepali, Swedish–American, German–American) |
| Decline to Answer | $n = 1$ |
| Highest Degree | |
| PhD | $n = 10$ |
| MS/MA | $n = 11$ |
| BS/BA | $n = 8$ |
| Junior/Senior Undergraduates | $n = 8$ |

for the present study represent a convenience sample and the interviews were collected as part of an expert–novice study to understand the development of geoscience expertise (Libarkin et al., 2011; Petcovic et al., 2011; Hambrick et al., 2012). Participants were selected for the expert–novice study on the basis of gender balance, geographic diversity, and a range of expertise, although the participants represent a convenience sample for the present study. The 37 participants in our sample ranged in expertise from undergraduate upper-level students who have completed one field geology course, in addition to other geology degree requirements, to PhD geologists who have been working in the field (Table II). Representation of women in our sample, 46%, was a focus for the researchers who gathered the sample and approaches representation of women in our American workforce at 47%, but our sample exceeds the approximately 30% representation women have in the geosciences workforce (Gonzales and Keane, 2011). Twenty-nine participants identified as White, with two additional participants identifying as Native American/White and Hispanic/White. Equitable representation of underrepresented minorities (Hispanics, African Americans, and Native Americans) was not a goal in the selection of the sample for this study and, at <1%, it falls far below their representation in the American workforce, which is approximately 25%. The representation in this sample is also below the population of underrepresented minorities in the geosciences, which peaked at 8.1% in 2008 and dropped down to 2.2% in 2009 (Gonzales and Keane, 2011). In exchange for two days of cognitive testing and a field-mapping task of a geological structure, participants were paid a stipend and travel expenses. The interview question for this study was asked at the end of a 45-minute long interview. Transcripts varied in length from 33 words response to 435 words. Subject responses were audio recorded and transcribed after the study.

## ANALYSIS AND RUBRIC DEVELOPMENT

This study employed an inductive approach, which allowed themes to emerge from the interview transcript, rather than using a theoretical lens to guide data collection and analysis (Glaser and Strauss, 1967; Erickson, 1986). The overarching goal of the analysis was to determine if there were consistent themes among participant responses. For the purposes of this study, analysis was conducted only on the portion of the transcript directly following the interview question: "How did you get interested in geology?"

The transcripts were reviewed independently by the two researchers to formulate lists of key words and to identify emergent themes. A rubric was then developed collaboratively, which included codes for groups of key words belonging to each of the emergent themes. Researchers then coded all 37 transcripts independently and discussed coding discrepancies to refine the parameters of the rubric. Following this refinement, the researchers each recoded 10% (four) of the transcripts. A two-way random effects intraclass correlation (ICC) was used as a measure of both interrater reliability and interrater agreement (LeBreton and Senter, 2008). A significant intercoder agreement and reliability of ICC = .807 ($p < .001$) was calculated using SPSS (version 20).

The researchers performed a second style of coding by assigning each phrase in a participant's transcript to one or more of the emergent theme categories. The assignments were tallied giving each participant a score for each of the theme categories. Eight randomly selected transcripts (20%) were coded independently by each researcher with very high agreement and reliability (ICC = 0.972, $p < .001$). With reliability and agreement established, one researcher coded the remaining 80% of transcripts, using the refined phrase-based analysis rubric.

### Limitations

An overall limitation of this study is the narrowly focused sample population of field geologists. The researchers gained access to 37 geologists through interviews that were conducted as part of an expert–novice study of geoscience knowledge, spatial ability, and field mapping skill (Libarkin et al., 2011; Petcovic et al., 2011; Hambrick et al., 2012). Therefore, this study includes a sample of convenience; however, the narrow focus provides a good measure of experiences for field geologists specifically, which may be compared in future studies to experiences of non-field geoscientists in general. Likewise, this study includes an ethnically and racially homogeneous population. This is difficult to avoid, given the lack of diversity in the geosciences.

Many participants were physically tired when they answered the interview question that serves as the target for this study. Participants were interviewed following a day of intense effort, including 30 minutes of cognitive testing, three hours of an introductory field-mapping task, and up to six hours of actual field mapping. Participants were offered refreshments and a brief break before the interview. Very little probing was done beyond the interview question; however, interviewers varied in the amount of probing based, in part, on the participants' fatigue levels. Each of the 37 interviews was conducted by a team of two interviewers, with each team including one of the principal investigators for the expert–novice study. Interviewer bias in the content of the probes may have focused the interview topic on early-childhood experiences versus college-age experiences. Seven of the 37 interviews included a probe about early experiences that may have led to their interest in geoscience, one interview included a probe about college experiences, and an additional six interviewees were probed for clarification on the setting or age of their recalled experiences.

## RESULTS

The coding rubric resulting from this iterative process is a nested coding scheme with several codes falling under three main thematic categories: Academic Experiences, Connections with People, and Engagement with Earth (Table III). The Venn diagram (Figure 1) models the researchers' thematic interpretations of the interview data and shows how experiences, such as "undergraduate," were referenced in different ways by participants (undergraduate professor vs. undergraduate class content/concepts vs. undergraduate field trip). We sought to preserve the temporal and contextual integrity of participant statements through the acknowledgment and categorization of events according to when and under what circumstances various experiences and people were mentioned.

Most participants mentioned items from multiple themes and subthemes during interviews. In the section below, we provide examples of these mentions and discuss the most common subthemes that emerged (greater than or equal to $n = 12$ of the 37 participants). The following three subsections are dedicated to an exploration of the major themes through participant quotes. It is important that the reader recall that these responses were elicited from the question, "How did you get interested in geology?" and that participants were not prompted with a structured interview protocol. The quotes herein are attributed to the participants by including their self-chosen pseudonyms in parenthesis.

### Academic Experiences

The Academic Experiences theme demonstrates the importance of undergraduate experiences for the recruitments of the geologists in this study. Most participants mentioned undergraduate courses ($n = 24$), including introductory courses ($n = 17$) as a critical experiences leading to their interest in geology.

> *"I became interested in geology when I took an introductory geology course . . . that was taught by the geology department called The Environment my first year of college."* (Ivy)

> *"It was just a course I took and it was so amazing, I couldn't believe it. And then it was a summer course. It was actually a field ecology course, but a third of it was geology. I said, 'Gimme a break. This can't be true.' So then I went back and took a geology class, and I was a biology major and the difference between the departments and the geology professors. I was like, "this is just too cool to miss."'* (Sacajawea)

More than a third of the participants mentioned switching to geoscience from another science, technology, engineering, or mathematics (STEM) field ($n = 14$).

> *"I was going to be physics major but then I realized, hey, there's this other subject where you can actually be outside a lot of the time and you get to tell a story about, figure out a story, how something happened and sort of seemed really neat to me. So I switched majors."* (Dingo)

Some of the participants describe very dramatic experiences in other majors leading them to declare a geoscience major. In some cases, negative experiences pushed them out of one domain and into the geosciences.

> *"I was going to be a physics major and I took the first physics for a major's class and hated it. Everyone was geeky, it was so hard. I would spend 10 hours on these stupid problems sets and I didn't like anyone in the class and it wasn't very fun . . . And I took a class in Earth History and I just absolutely loved it."* (Moly)

Overall, 34 of the 37 participants explicitly mentioned an academic-related experience in their interview.

### Connections with People

Connections with People figure prominently as critical influences for the participants. Specifically, family ($n = 15$) and college professors ($n = 12$) are the most common people influencing the participants' interest in geology. Various family members played a role in this process.

> *"My grandfather used to take me to the rock and gem shows when I was like four and up until I was a teenager. And I guess that's what started it."* (Riley)

> *"And then my parents both took some geology in college, so they were very encouraging with my interests."* (Parique)

In some cases, the teacher's enthusiasm alone influences the interest in geology.

> *"I had a really good teacher who just was very excited and passionate about what she did. And that sort of, that carried over to me."* (Caution)

In other cases it was a curricular choice made by the professor that influenced the participant's interest in geology.

> *"[The course] was taught by a professor whose field area was about 30 miles east of my home in New Hampshire. So the things that he talked about and examples that he had in his class for the entire 50 students in the class were all examples that I knew of, or at least had heard of or had maybe gone on a picnic to some day."* (Ivy)

Overall, 33 of the 37 participants referred to a person as an important influence in the development of their interest in geology.

**TABLE III. Emergent themes, subthemes, and key words. Transcripts were coded into the following theme and subthemes categories (e.g., School) if the participant specifically mentioned any of the key words in each subtheme.**

| Emergent Theme A: Academic Experiences |
|---|
| School |
| Any |
| Elementary |
| Middle school (junior high) |
| High School |
| Community college |
| Undergraduate |
| Specific age mentioned |
| Introductory-level geosciences course |
| Transferred into geoscience after start of college |
| From other science undergraduate programs |
| From nonscience undergraduate program |
| At graduate level |
| After work experience |
| Other disciplines mentioned |
| STEM disciplines: physics, chemistry, biology, engineering, environmental sciences, mathematics |
| Non-STEM disciplines (i.e., business, philosophy) |
| Not restricted to mention with "major" |
| **Emergent Theme B: Connections with People** |
| Family |
| Family |
| Mother |
| Father |
| Grandmother |
| Grandfather |
| Non-Family |
| K–12 teacher |
| College professor |
| Peer(s)/friend(s) |
| Academic mentor |
| Nonacademic mentor |
| **Emergent Theme C: Engagement with Earth** |
| Work Experience |
| Work |
| Job |
| Hire(d) |
| Academic |
| K–12 |
| Pre-college |
| College |
| Field course/camp |
| Childhood |
| Family travel |
| Regional geology |
| Museums |
| Scouts |
| Recreation |
| Outside |
| Hiking |
| Rock climbing |
| Travel |
| Objects |
| Books |
| Rocks |
| Fossils |
| Dinosaurs |
| Landscape/landforms |
| Maps |

### Engagement with Earth

Engagement with Earth is a major theme that emerges from the participant transcripts. Roughly half of the geologists in this study ($n = 17$) report being influenced by the regional geology of either the area where they grew up or somewhere they traveled as a young person.

> *"I grew up on the coast just south Boston, and that's about the southern extent of glaciation. Everything south of there pretty much is recessional, so it's all depositional. But there's some fantastic exposures and all that beautiful pinkish granitic rock, which is Precambrian and it's cross-cut by those green diabase dikes. I mean if we had a Google Earth connection here I could show you the dikes that got my interest, literally. And, you know, I was interested in that, and there was some huge erratics out in the woods that we would clamber on as kids and now it's neat. And there were glacial striations in the ledges in my parents' backyard."* (Tank)

Some participants expressed the sense of awe that studying geology inspires in them.

> *"[It's] just exciting being outside and looking at the Earth and really experiencing the world in a really different way that was completely different than I thought it before."* (Billy)

Many participants also discuss outdoor recreation as a reason for their interest in geology.

> *"I enjoyed the rocks, I do rock climbing and climbing I became interested in the rocks and I wanted to know more and more about them."* (Iancu)

> *"I like backpack[ing] and traveling, looking at nature and geology is a good related field."* (Mountain Man)

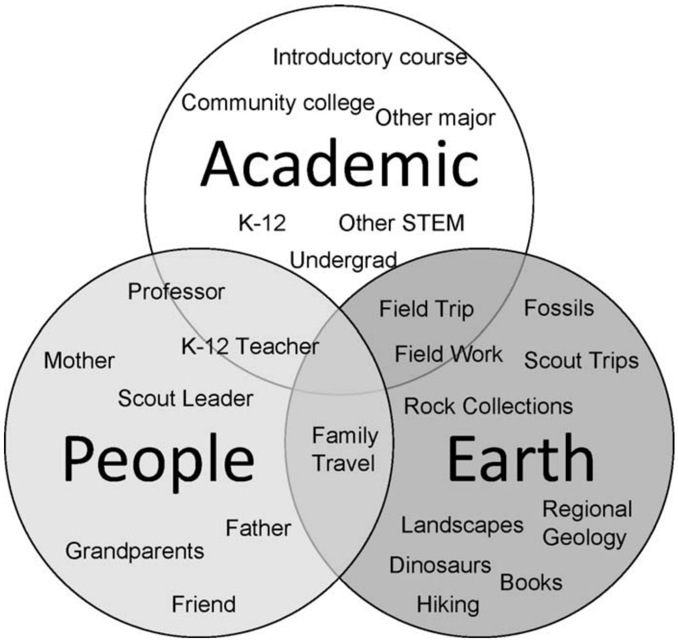


**FIGURE 1. Academic Experiences, Connections with People, and Engagement with Earth themes emerged from the coding rubric. Each theme has several subthemes that were identified by explicit mention in the participants' interviews. Some of the subthemes are overlapping (e.g., a professor is part of the undergraduate experience [Academic, People], or family travel provides a transformative experience [People, Earth]).**

Another subtheme, we named "objects" (e.g., rocks, fossils, maps, landscapes), represents the physical things that inspired participants to study geology (Table III).

> *"I decided to chase a childhood love, and that's why I chose geology. I always collected rocks, I had tons of them."* (Samson)

> *"When I was young long time ago, we used to go sailing in Wishabi, Alaska. And the landscape there is really new. I mean within years, possibly decades, its been uncovered by ice and there is so little vegetation that you can see everything. You can see all the geology. So I think that's what sparked my interest. Being able to see the landscape."* (Parique)

Overall, 35 of the 37 participants were inspired by Earth-related content through informal exposure outside of formal schooling, enjoyment of recreation in nature, or due to awe of the natural world.

### Demographics and Themes

The second style of transcript analysis was conducted to identify any relationships between the emergent themes from participants' interviews and their individual attributes such as age, status as an undergraduate, years since highest degree, and gender. Each interview was analyzed, phrase by phrase, and each phrase was assigned to one of the three themes: Academic Experiences, Connections with People, Engagement with Earth. The assignments were tallied giving each participant a score for each of the three categories. For example, the interview response for one of our participants, Sam, was coded as follows:

> *"I grew up on the East Coast on Long Island and I had never been to the mountains before and got a job on a trail crew in North Cascades. And I was working with a woman who had just taken a Geology 101 class, and so I was exposed to mountains and geology and I know that that's what I wanted to do. So I just went back to school after that summer and changed my major. Became a geologist."* (Sam)
>
> Analysis:
>
> Phrase 1: "*I grew up on the East Coast on Long Island and I had never been to the mountains before*" (Theme[s]: Earth)
> Phrase 2: "*. . . and got a job on a trail crew in North Cascades. And I was working with a woman who had just taken a Geology 101 class, and so I was exposed to mountains and geology and I know that that's what I wanted to do.*" (Theme[s]: People, Academic, Earth)
> Phrase 3: "*So I just went back to school after that summer and changed my major. Became a geologist.*" (Theme[s]: Academic)

Therefore, the themes represented in Sam's response are: People (1), Academic (2), and Earth (2).

Nonsignificant Spearman correlations indicate that there is not a significant relationship between the three theme counts and participants' age or years since highest degree. The participants were split into two groups, undergraduate or nonundergraduate, to evaluate if there are differences between graduated geologists and upper-level undergraduates. There were no significant Spearman correlations for the undergraduate group; however, there is a significant correlation between participants' with codes for Academic and People themes for the nonundergraduate participants ($r(36) = .440$, $p < .015$). Therefore, the inclusion of undergraduate students in this sample may have a moderating effect on the statistical analyses but is not responsible for the correlations performed on the sample group as a whole.

A Spearman correlation was conducted with the three theme counts and gender. There is a moderate relationship between the gender of participants and those who mention Academic influences ($r(36) = .356$, $p <.05$). A $t$-test was run to evaluate the significance of the difference in mean scores of females versus males. A significant $t$-test shows that males mention Academic experiences to a greater extent than females ($t(36) = 2.136$, $p = .04$). No significant gender differences appeared between our participants for those mentioning People or Earth experiences.

## DISCUSSION

The three emergent themes from the present study validate previous findings that academic experiences, relationship with family, and experiences with Earth are important for fostering choice and participation in the geosciences (Table IV). Academic experiences generally, and undergraduate geoscience courses specifically, are well established in the literature as a critical component of recruitment and retention of students (Holmes and O'Connell, 2003; Levine et al., 2007; Baber et al., 2010; Houlton,

**TABLE IV. Influences on recruitment and retention. Although the focus of most studies is on programmatic components of academic programs, nonacademic relationships and experiences (bold) have fostered choice and participation in the geosciences.**

| | Levine et al., 2007 | Houlton, 2010 | Hoisch and Bowie, 2010 | Present Study |
|---|---|---|---|---|
| **Influences** | | | | |
| Academic coursework | X | X | X | X |
| Awareness of geosciences | X | | | X |
| Interest in science | | | X | |
| Geoscience careers | X | | | |
| Faculty | | X | | X |
| Field trips | X | X | | X |
| **Family** | | X | X | X |
| **Outdoor experiences** | X | X | X | X |
| **Travel** | X | X | X | X |
| **Rocks, fossils** | | X | X | X |
| **Local geology** | | X | | X |

2010). Results presented here suggest that academic experiences may be more influential for males than for females. The frequent mention of family influences on geoscience interest underscore the importance of expanding recruitment and retention models beyond formal academic interventions. Many of the subthemes associated with the theme Engagement with Earth may also be categorized as informal learning experiences. Childhood experiences with family travel, place-based geology, museums, and scouts occur beyond the scope of formal learning environments. Most of the 37 participants in this study attribute their interest in geology to informal opportunities to engage with Earth topics.

Prior studies utilizing deductive methodologies, such as critical incident interviews, target the experiences that influence geoscientist recruitment (Levine et al., 2007; Houlton, 2010). Although theoretical models of recruitment based on academic levels are helpful for identifying ways the formal education system may recruit more geology majors, they may underrepresent the importance of nonacademic experiences on career choice. Houlton's (2010) undergraduate-oriented study groups call pre-college influences as "innate attributes/interest sources" and "pre-college critical incidents." Levine's et al. (2007) academic-oriented pipeline does not identify any indicators pre-middle school and uses "familial factors," "extracurricular activities," and "geoscience awareness" to represent the nonacademic "Middle/High School Indicators." The main treatment of nonacademic experiences in this research is to aggregate the various experiences into a form of "other" (such as "miscellaneous") with disparate mentions of informal learning experiences scattered throughout the findings.

In contrast, informal science experiences emerge prominently in the present study with 35 of the 37 interviewees identifying Engagement with Earth as influential in the development of their interest in geology. A study of persistence of women in the professoriate used an approach similar to the present study and found a similarly significant contribution from nonacademic experiences (Holmes and O'Connell, 2003). Focus groups with randomly selected male and female geoscientists from several American universities were asked the question, "What brought you into the geosciences?" One-third of all participants in Holmes and O'Connell's (2003) study identified engaging undergraduate courses or professors as their top reason for choosing the geosciences; however, approximately one-quarter of the participants identified a love of the outdoors or the subject matter, and one-fifth of the participants identified a family member as contributing to their interest in the geosciences. Holmes and O'Connell (2003) and the present study reveal impressive contributions to choice of geoscience career from family experiences and engagement in outdoor recreation.

## Role of the Affective Domain in the Geosciences

Although the inductive approach frees our study from an imposed theoretical structure prior to coding, a posteriori analysis of the emergent subthemes show some promising alignment with the affective domain literature. Van der Hoeven Kraft et al. (2011) proposed a theoretical model for understanding the influence of the affective domain in motivating student learning in the geosciences. The work draws from a suite of disciplines, including educational psychology, environmental education, and art education, and suggests that student interest and value of geoscience content can be positively impacted when student motivation, emotion, and "connections with Earth" are integrated in the classroom setting (van der Hoeven Kraft et al., 2011). While an affective-oriented theoretical framework was not used as a basis for the present study, subthemes within Engagement with Earth appear to parallel the work of van der Hoeven Kraft et al. (2011). Specifically, the alignment of our emergent subthemes with the concepts of *place attachment* and *connections to aesthetic* aspects of Earth are worthy of further examination.

Semken (2005) identifies "sense of place" as "the meanings of and the attachments to a place held by a person or group" (p. 149), and describes the importance and role of addressing sense of place in geoscience education for American Indians and Alaska Native undergraduates. *Place attachment*, specifically, may be defined as the emotional connections with a place (van der Hoeven Kraft et al., 2011). In the present study, the emergent "Engagement with Earth" theme was identified largely by the frequent mentions of regional geology in 17 of the 37 interview responses (see interview responses from Tank and Ivy in the Results section for examples). The pervasiveness of the regional geology subtheme alludes to the importance of place attachment for developing interest in geology and may support the theoretical model proposed by van der Hoeven Kraft et al. (2011).

*Connections with aesthetic* is defined as encompassing the collection of concepts associated with "aesthetic appreciation" and "a sense of awe" for landscapes or geological processes (van der Hoeven Kraft et al., 2011, and references therein). Interviewees in the present study describe their awe about viewing and understanding landscapes (see also interview quote from Parique, above).

> *"Well, I was always interested in the outdoors. And I remember driving in Wyoming, and looking at the shape of the land that I kept thinking what made it look like that?"* (Zephyr)

Within the object subtheme, we categorized landscapes, along with rocks, fossils, books, dinosaurs, and maps. The emotion with which participants express their appreciation with the aesthetic is clear in Tank's description of the "*fantastic exposures and all that beautiful pinkish granitic rock*" that inspired his interest in geology. While further study is needed to better understand the relative contributions of affective Earth connections in the recruitment and retention of geoscientists, generally, the strong presence of affective place-oriented mentions in the interview responses of this group of field geologists suggests that affective connections with Earth play a key role in the development of field geologists.

## CONCLUSION

Emergent themes from the present study of 37 successfully pipelined geologists highlight that informal, or nonacademic, learning experiences are a vital element to the recruitment and retention of field geologists. Specifically, role of family, engagement in outdoor recreation, and personal experiences with local geology are key components for interest development. Our findings align with the "connections to Earth" element of van der Hoeven Kraft and colleagues' (2011) framework, which provides support for motivating students in the geoscience classroom. Previous studies' treatment of nonacademic learning experiences as "other," or disparate fragments, imbues them with a sense of inaccessibility and beyond the purview of formal education. However, formal educators at all levels can work with informal educators to fortify recruitment and retention programs. Future studies examining recruitment and retention should include affective and informal components relevant to field geology. This would enrich our understanding of the relative influence of informal experiences and help us better attend to fostering positive affective experiences in both the formal and informal settings.

Further research is needed to improve our understanding of the importance and roles played by the three key components identified in this study (Academic, People, and Earth) for geologists from other subdisciplines and other STEM professionals. We caution the overinterpretation of these findings beyond field geologists. Geoscientists from other subdomains may not share the kinds of experiences reported by our sample population of field geologists and may instead identify experiences more akin to those of other lab-based scientists. This study provides a thorough analysis of the experiences of field geologists, which may serve as a comparison sample for future studies of other non-field-geologists and scientists in general.

Research with underrepresented populations in the geosciences must be continued alongside research on well-represented groups so we can achieve better resolution of the details that comprise the differences in pathways of well-represented and underrepresented populations. A prior study of successfully pipelined underrepresented geoscience students reported that students cite outdoor experiences as positive; however, other literature suggests that some cultures may view fieldwork in a negative light (Levine et al., 2007). Although we identify promising new directions for developing interest in future cohorts of geologists based on successfully pipelined field geologists, future studies should evaluate experiences of those who have not been successfully retained. This will allow for the development of targeted funding, and programmatic and policy interventions that are rooted in research.

In summary, many geologists are recruited through undergraduate introductory courses. Positive relationships with professors can be a critical influence in developing a person's interest in geology. However, students arrive with substantial nonacademic experiences that may promote their interest in geology. For tertiary geoscience educators it is vital, especially in introductory courses, to recognize that students come to these courses with years of experience working towards, against, or tangentially to their success in geoscience courses. It is also important to keep in mind the powerful formal and informal roles undergraduate professors have in the lives of students, both majors and nonmajors. For those interested in recruiting more professionals to the geosciences, consider how efforts can be organized to support sustainable nonacademic interventions. For researchers, broader impacts components of proposals that include work with communities, museums, and nonacademic groups, such as scouting programs, may provide geology-related experiences that are fertile ground for growing future geologists.

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