3-2023

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Research Paper

GEOSPHERE

GEOSPHERE

https://doi.org/10.1130/GES02581.1

6 figures; 7 tables; 1 set of supplemental files

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CITATION: Shafer, G.W., Viskupic, K., and Egger, A.E., 2023, Critical workforce skills for bachelor-level geoscientists: An analysis of geoscience job advertisements: Geosphere, https://doi.org/10.1130/GES02581.1.

Science Editor: Andrea Hampel
Associate Editor: Cinzia Cervato

Received 2 August 2022
Revision received 28 October 2022
Accepted 15 November 2022

Published online 9 February 2023



# Critical workforce skills for bachelor-level geoscientists: An analysis of geoscience job advertisements

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## ABSTRACT

**Understanding the skills bachelor-level geoscientists need to enter the workforce is critical to their success. The goal of this study was to identify the workforce skills that are most requested from a broad range of geoscience employers. We collected 3668 job advertisements for bachelor-level geoscientists and used a case-insensitive, code-matching function in Matlab to determine the skills geoscience employers seek. Written communication (67%), field skills (63%), planning (53%), and driving (51%) were most frequently requested. Field skills and data collection were frequently found together in the ads. Written communication skills were common regardless of occupation. Quantitative skills were requested less frequently (23%) but were usually mentioned several times in the ads that did request them, signaling their importance for certain jobs. Some geoscience-specific skills were rarely found, such as temporal understanding (5%) and systems thinking (0%). We also subdivided field skills into individual tasks and ranked them by employer demand. Site assessments and evaluations, unspecified field tasks, and monitoring were the most frequently requested field skills. This study presents the geoscience community with a picture of the skills sought by employers of bachelor-level geoscientists and provides departments and programs with data they can use to assess their curricula for workforce preparation.**

## 1 INTRODUCTION

Bachelor-level geoscientists represent the majority of the current geoscience workforce (U.S. Bureau of Labor Statistics, 2022). They are hired in many occupations (e.g., hydrologist, geologist, and environmental scientist) across industry sectors for natural resource extraction (e.g., oil and gas and mining) and by federal, state, and local governments. Over the next decade, positions for bachelor-level geoscientists are forecast to increase by as much as 10% (National Center for O*NET Development, 2021). We ask: Are geoscience departments preparing undergraduate students with the skills and abilities needed to enter and succeed in the workforce?

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To address this question, we need to understand employers' expectations of bachelor-level geoscientists. Some undergraduate geoscience programs cultivate professional relationships with industry employers to ensure successful student transitions to the workforce (Wilson, 2019). These types of professional relationships can facilitate communication between employers and potential job applicants; however, they provide limited and potentially idiosyncratic evidence of employer expectations. Instead, for many new graduates entering the workforce, job advertisements and interviews will be their first communication with potential employers.

In job advertisements, employers communicate the nature of the position (i.e., work to be performed or description of the work environment) and the required and preferred skills they seek in applicants. Many job seekers use online job aggregators to search for relevant opportunities, and these platforms are widely used by employers. Therefore, to develop a broad view of the skills geoscience employers across industry sectors are seeking, we analyzed 3668 advertisements collected from online job aggregators during two six-month periods.

Our data set includes employers from all industry sectors and outlines the current skill sets requested of bachelor-level geoscientists. Our work provides the geoscience community with a picture of the skills graduates will need to enter the workforce. With this information, geoscience programs can assess their curricula and determine the extent to which they are providing students with the opportunity to practice workforce skills, communicate to students the skills they will be expected to have for the professional paths they choose to pursue, and demonstrate to students how their coursework and experiences prepare them for the workforce.

## 2 BACKGROUND

### 2.1 Skills in the Geosciences

Previous studies have offered some insight into geoscience workforce skills. *Vision and Change in the Geosciences: The Future of Undergraduate Geoscience Education* (Mosher and Keane, 2021; referred to as *Vision and Change* throughout) brought academics and employers together in working groups to develop a list of geoscience workforce skills. Nyarko and Petcovic (2022) conducted focus groups with geoscience employers to identify desired teamwork competencies. Shafer et al. (2022) analyzed ~1200 ads to provide an overview of the most frequently requested skills.

Mosher and Keane (2021) describe a wide spectrum of skills, but the number of employers who participated in their study was limited (n = 46), and 26% of the employers who participated in *Vision and Change* represent the oil and gas industry, which employs only 6% of bachelor-level geoscientists (Keane et al., 2021). Similarly, Nyarko and Petcovic (2022) focused on a small sample of hydrogeology and environmental geology employers. While the input from employers in these studies is valuable and insightful, our study takes a different approach. We wanted to consider the broad range of diverse careers in the geosciences and identify desired skills across this range to help programs evaluate how well they are preparing undergraduates to enter and succeed in the workforce.

### 2.2 Research Questions

To help undergraduate geoscience programs prepare students for the workforce, we ask: (1) Which skills are employers currently seeking when hiring bachelor-level geoscientists?

(2) How do requested skills vary among different geoscience occupations? The goal of our work is to provide a comprehensive snapshot of the most in-demand skills.

### 2.3 Job Advertisements as a Data Source

By analyzing job advertisements, we can assess the desired qualifications of an ideal job candidate. Importantly, we can gather information from a wide range of employers from all industry sectors, and the sample of advertisements represents the distribution of fields in which bachelor-level geoscientists are being hired at the time. Data sets from job advertisements can be robust and extensive. For example, Rios et al. (2020) compiled over 140,000 advertisements using web-scraping technology and analyzed them for twenty-first–century skills for undergraduate students in any field of study.

Using online job advertisements as a data source has some limitations. First, we assume that the employer is listing all critical skills and qualifications in the ads. However, many online advertising platforms charge by ad length, so employers may limit the information they include. Second, our results may be biased in favor of companies who recruit online. Some industry sectors may hire primarily through word-of-mouth references or recruiting at conferences or directly from specific academic programs. We acknowledge these limitations and seek to overcome them by including a large number of ads in our study.

## 3 METHODS

### 3.1 Identifying Geoscience Job Advertisements

We gathered job advertisements (ads) from online search engines using a set of 28 search words and phrases (e.g., environmental science, geology, and geochemistry; see Supplemental Material File S1[1]) from the 2018 American Geosciences Institute Status of the Geoscience Workforce Report (Wilson, 2019). From May to November 2020, and again from May to November 2021, we used these search words to manually retrieve ads weekly from four online search engines: USAJobs.gov, Careerbuilder.com, Collegerecruiter.com, and Indeed.com. Our first period of sampling occurred during the initial onset of COVID-19, and we were concerned that our sample may inaccurately reflect the geoscience job market. Therefore, we conducted additional sampling over the same time period in 2021. No significant differences were noted in the distribution of ads between the two time periods, and we thus combined the ads into a single data set. We chose USAJobs.gov because the federal government is a significant employer of bachelor-level geoscientists (Keane et al., 2021). We chose Indeed.com, Careerbuilder.com, and Collegerecruiter.com based on conversations with undergraduates about which search engines they frequently use. Indeed.com provided the most advertisements (58%) followed by USAJobs.gov (34%), Careerbuilder.com (5%), and Collegerecruiter.com (3%). However, many advertisements listed on Careerbuilder.com and Collegerecruiter.com were also cross-listed on Indeed.com. We considered Indeed.com as our first source for downloading job advertisements, and Careerbuilder.com and Collegerecruiter.com thereafter. Any ads cross-listed with Indeed.com are reported in the Indeed.com percentage. All federal government advertisements are reported with USAJobs.gov percentages as all federal government hiring must be completed though USAJobs.gov.

We limited our sample to ads that required or preferred a bachelor's degree in a geoscience-related field and less than five years of experience. We manually removed any duplicate ads that were cross-listed on multiple search engines. If more than one position was listed in a single ad, each position was treated as a unique ad to accurately reflect the current job market. After removing duplicates and expanding ads with multiple available positions, our data set consisted of advertisements for 3668 unique geoscience jobs.

We recorded location (by state), occupation (e.g., geologist and environmental scientist), and industry sector (e.g., oil and gas and federal government) for each position. Occupations were initially defined using the U.S. Bureau of Labor Statistics 2018 Standard Occupational Classification Systems (BLS, U.S.

[1]Supplemental Material. One-page Microsoft Word document containing search words used to identify job advertisements and a Microsoft Excel file containing additional results not shown in Table 7. Please visit **https://doi.org/10.1130/GEOS.S.21706625** to access the supplemental material, and contact editing@geosociety.org with any questions.

Bureau of Labor Statistics, 2018). However, the BLS system classifies several occupations—geochemist, oceanographer, petrologist, and volcanologist—as "geoscientist." Given the focus of this work, we chose to list these occupations separately. We used industry sectors identified by Wilson (2019) to classify ads based on information from company websites. If no website was available, the industry sector was determined from the information provided in the ad alone. If a single industry sector could not be identified, the ad was classified in the Professional, Scientific, and Technical Services sector.

### 3.2 Developing Codes

To consistently identify requested skills in each ad, we developed a set of codes. All three authors began by using the skills in *Vision and Change* (Mosher and Keane, 2021) to manually code a subsample of ads (n = 20). During this initial coding step, we noted skills that were observed in the ads but were not present in *Vision and Change* (Mosher and Keane, 2021) and added these as emergent codes. We grouped skills by using and expanding on a scheme outlined by Viskupic et al. (2021). Additionally, we identified qualifications in the ads that are not skills, such as professionalism and attention to detail. We categorized these as "dispositions," defined as personal qualities or characteristics of an individual, and coded for these as well. After two rounds of initial coding, we finalized a list of 41 codes consisting of 35 workforce skills and six dispositions (Table 1). Each author completed a final round of coding to calculate inter-rater reliability; we had >90% agreement for all codes.

Field skills and computer skills are important from both academic (Stokes and Boyle, 2009) and employer perspectives (Mosher and Keane, 2021), but these are broad categories that include diverse, specific skills. For example, geologic mapping, collecting water samples, and surveying could all be referred to as field skills. Likewise, tasks that include sending email, using a spreadsheet, or coding in Python can be referred to as computer skills. Therefore, we subdivided field skills and computer skills beginning with examples from our previously coded ads. The three authors again conducted multiple rounds of coding to fully develop our list of sub-codes. We completed a final round of coding to calculate our inter-rater reliability and had >90% agreement for all codes. Our final lists contain 22 field-skill codes (Table 2), including unspecified field skills, which is defined as the need for field skills when no details are provided (e.g., "some field work required"), and three computer skill codes (Table 3).

### 3.3 Coding Process

We automated coding by developing a case-insensitive, code-matching model in Matlab. Automated coding is an established method that is more consistent than manual coding (Weitzman, 1999), particularly for a large data set such as ours. To reduce the likelihood of under-coding, we strengthened the list of examples for each skill that would be used by the Matlab model by hand-coding ~10% of the ads. After finalizing the list of code-phrase examples, we trained the model in Matlab against the hand-coded ads. During the training process, we minimized the tendency of the model to detect false positives (type 1 errors), in which the model would use a defined example phrase to code text as a skill that should not be coded. For example, we began with the field-skill code-phrase "installing and maintaining equipment" but were unable to separate it from installing and maintaining equipment in other non-field settings. To quantify the rate of false positives for each code phrase example, we randomly sampled advertisements from the hand-coded subset and compared the model output to the hand-coded results. If we detected a false positive rate above 5% for any code phrase example, we removed that example from the list. Once the model was trained, we used Matlab to scan the remaining ads.

### 3.4 Data Management and Analysis

Once the codes were established and automated, we analyzed the ads in two ways. First, we recorded the presence/absence of the codes in each ad to determine the proportion of advertised jobs that requested each skill. Second, we recorded the number of instances of the skills in each ad, considering this as a proxy for the importance of the skill for the position. Using the total number of instances, we correlated codes to identify clusters of skills that were more likely to occur together.

## 4 RESULTS

### 4.1 Job Characteristics

The 3668 advertisements that met our criteria came from 1125 employers spanning 19 industry sectors (Fig. 1) and 21 occupations. Most jobs were in the federal government (38%); environmental services (24%); state and local government (10%); and professional, technical, and scientific services (9%) industry sectors (Fig. 1). Environmental scientist (25%), geoscientist (19%), geologist (15%), and soil and plant scientist (14%) were the most common occupations, followed distantly by GIS analyst (4%), geo-related engineer (4%), and meteorologist (3%). Figure 2 shows that some occupations (environmental scientist, geoscientist, and geologist) occurred across all industry sectors, whereas other occupations were almost exclusively requested by one sector (for example, 94% of the soil and plant scientist positions were within the federal government sector).

The greatest number of jobs in our sample were located in California (10%), Texas (5%), and Florida (4%) (Fig. 3A). Normalized by state population, the distribution is skewed toward less populous but resource-rich states such as Alaska, Montana, and Wyoming (Fig. 3B).

TABLE 1. SKILL AND DISPOSITION CODES

| Code group | Code | Description of code | Examples |
|---|---|---|---|
| Work Setting | Field Skills | Conduct any work operations in a field setting. | Perform site visits to gather data; conduct field investigations; perform tasks in varying field conditions. |
| | Reporting from the Field | Report findings from a field setting. | Produce reports from the field; field reporting (primarily for meteorologists). |
| | Lab Skills | Conducting any work operations in a lab setting. | Prepare samples for laboratory analysis; operate the X-ray fluorescence spectrometer. |
| Data Skills | Record Keeping/Documentation | Record or file selected useful information. | Log information; record data; keep track of procedures; document and upload notes; compile and complete field notes. |
| | Data Collection | Effectively collect and curate data. | Take water and soil measurements; collect data. |
| | Data Processing | Manipulate data. | Process data; review data, input data into analytical software; perform data review. |
| | Data Interpretation | Systematically use data to arrive at a conclusion or to make inferences. | Interpret field data; use data as indicators; analyze data; data evaluation. |
| | Large Data Management | Effectively manage or navigate large datasets or databases. | Maintain or manage large data sets; set up a database. |
| Scientific Thinking | Research Information | Search for, locate, extract, organize and evaluate relevant information. | Gather information; research information needed to address a question. |
| | Problem Solving/Critical Thinking | Use knowledge, facts, and data to effectively identify and solve problems. | Troubleshoot; use judgment to make adjustments; identify viable remedial solutions. |
| | Apply Skills in New Scenarios | Use learned skills in different situations. | Innovative thinking; creativity; create and evaluate innovative ideas. |
| Planning and Leading | Planning | Develop strategies to accomplish tasks/goals. | Set up field projects; plan and permit; directly support plans; develop scope of work. |
| | Project Management | Manage project essential items to ensure progress or completion of projects. | Manage projects; coordinate the work of contractors; oversee operations. |
| | Leadership | Organize, lead, influence, or guide others. | Serve as leader; ability/desire to lead tasks; coach or mentor. |
| | Supervision and Training | Manage and delegate responsibilities and tasks by observing, guiding, and instructing. | Train others; supervise; oversight of others; manage site inspectors. |
| | Time Management | Organize and plan the amount of time given to different tasks. | Meet deadlines; complete work in timely manner; manage several tasks/projects simultaneously. |
| Communication | Written Communication | Communicate in written form. | Write reports; excellent written communication skills. |
| | Oral Communication | Communicate in oral form. | Verbal communication; good presentation skills. |
| | General Communication | Communicate in an unspecified format. | Interact with the public; provide advice; ability to communicate; explain programs and procedures. |

(*continued*)

TABLE 1. SKILL AND DISPOSITION CODES (*continued*)

| Code group | Code | Description of code | Examples |
|---|---|---|---|
| Interactions with Others | Work as Part of a Team | Work or collaborate with others. | Collaborate, work as part of a team, team player, work in a two-person crew, alongside…; work with onsite drilling crews. |
| | Work Independently | Work alone or without immediate supervision. | Work independently, work with minimal supervision. |
| | Customer/Client Relations | Interact effectively with customers/clients. Focus is on one-on-one settings. | Interact with clients; customer relations; consult with clients. |
| Computation and Technology | Quantitative Skills | Manipulate data and use numerical evidence systematically. | Statistical analysis; analysis of graphs; develop and review cost estimates. |
| | Computer Skills | Use computers to produce a product. | Computer work; ArcGIS; proficient in the use of computers; computer literate. |
| | Equipment Maintenance and Calibration | Ensure equipment functions consistently through proper maintenance and calibration. | Calibrate equipment; install, maintain, and service recording equipment; mechanical inclination. |
| Physical | Physical Abilities | Perform physically demanding acts (more than office-level lifting). | Lift 25 lbs.; carry; hike; physical exertion; traverse difficult terrain. |
| | Driving | Drive a vehicle. | Drive a vehicle; must have a valid driver's license. |
| Safety | Follow Safety Protocols | Follow established safety protocols and procedures. | Follow established safety procedures; ensure safety of operations. |
| | Hazardous Waste Operations and Emergency Response (HAZWOPER) Training | HAZWOPER certification or ability to obtain. | HAZWOPER training; Occupational Safety and Health Administration 40-hour. |
| Geoscientific Thinking | Spatial Understanding | Think about, reason, understand, or manipulate objects spatially. | Create maps and cross-sections; use maps; analyze spatial data. |
| | Temporal Understanding | Think about, reason, or understand changes over time periods. | Complete spatio-temporal analysis; forecast (weather, earthquake). |
| | Interdisciplinary Thinking | Consider and incorporate multiple disciplinary perspectives. | Work in interdisciplinary teams, work with different disciplines. |
| | Systems Thinking | Think about, visualize, or understand concepts as a system. | Systems thinking, systems approach, think of Earth as a complex, open, and dynamic system. |
| | Manage Uncertainty | Understand change and adapt when necessary. | Be adaptable. |
| Dispositions | Professionalism | Uphold a professional standard defined by the employer. | Maintain professional demeanor. |
| | Positive Attitude | Maintain a positive mindset or attitude. | Good/positive attitude. |
| | Desire to Learn | Eagerness to learn new ideas, concepts, or materials. | Develop new capabilities; curiosity; intellectually curious. |
| | Attention to Detail | Thoroughness when accomplishing tasks or responsibilities. | Detail-oriented; organized. |
| | Work Ethic | Believing in hard work as a moral good. | Strong work ethic; hard working. |
| | Initiative | Starting or completing a task without instruction. | Motivated self-starter; self-driven. |

TABLE 2. LIST OF FIELD-SKILL CODES

| Code group | Code | Description of code | Examples |
|---|---|---|---|
| Water | Surface Water Sampling | Directly measure or collect data from surface water bodies. | Discharge measurements; water-level data collection. |
| | Groundwater Sampling | Directly measure or collect data from groundwater storages. | Collect groundwater data; aquifer testing; groundwater sampling. |
| | Water-Quality Measurements | Measure water quality in the field. | Perform routing water-quality measurements such as water temperature, specific conductance, pH, dissolved oxygen, and alkalinity. |
| | Well Monitoring | Progressively check wells in the field. | Monitor wells, production wells, and aquifer storage and recovery wells. |
| | Pump/Well Testing | Test wells in the field. | Conduct well performance and aquifer testing; conduct pump tests. |
| Sampling | Geologic Sampling | Field collection of geologic samples. | Geologic sample collection and description; geologic exploration tasks. |
| | Drilling/Logging Wells | Participate in on-site drilling operations or identification of drilling-core samples. | Recognize and pick the geologic formations represented in core and cuttings; log drill cores. |
| | Soil/Erosion Data | Collect soil/erosion data from the field. | Collect surface erosion data on-site in a watershed; describe soil lithology. |
| | Monitoring | Repeatedly check the progress or quality of something in the field. | Repeated collection of data; noise monitoring; conduct onsite monitoring. |
| Surveying and Spatial | Surveying | Determine field area dimensions through various surveying techniques. | Conduct surveys; utilize surveying equipment. |
| | Wetland/Stream Delineation | Determine the precise boundaries of wetlands or streams in the field. | Wetland/stream delineation and mitigation. |
| | Geologic Mapping | Map the geologic elements of a field area using various techniques. | Geologic mapping; create map of deposits. |
| | Use GPS | Use a global positioning system (GPS). | Use GPS technology to document the location of critical features at the site. |
| | Map Reading | Read, understand, and interpret a map. | Read and use geologic maps; utilize maps. |
| Evaluation | Site Assessment/ Evaluation | Perform a comparison of a field site to a specific standard. | Assess sites for mitigation potential; environmental site assessments. |
| Engineering and Equipment | Inspection | Examine something in the field to assess its overall quality. | Inspect erosion and sediment control measures at commercial, residential, industrial, and highway construction projects; perform field inspections. |
| Planning, Overseeing, Documenting | Plan Field Work | Develop strategies to accomplish field-specific tasks/goals. | Prepare a variety of plans and specifications related to hydrogeological field activities; plan field activities. |
| | Ensure Field Safety | Ensure that safety procedures are followed, and safe operations occur in the field. | Ensure projects are performed safely; preparation and implementation of health and safety plans. |
| | Oversee Field Work | Observe and manage field activities. | Construction oversight; oversee well installation. |
| | Observe and Document Field Conditions and Activities | Make observations in a field setting and record those observations. | Observe and note hydraulic and environmental conditions; complete data entry to capture field activities. |
| General | Unspecified Field Tasks | Perform field work of an unspecified nature. | Perform tasks in varying field/office conditions; some field work required. |

TABLE 3. LIST OF COMPUTER SKILL CODES

| Code group | Code | Description of code | Examples |
|---|---|---|---|
| Computer Skills | Basic | Use a computer to perform basic operations or operate commonly used programs. | Proficient use of Microsoft Office products; send/receive emails. |
| | Coding | Use coding software to perform tasks. | Capable of using MATLAB, Python, or R to manage data sets. |
| | Specialized Software | Use software beyond commonly used programs. | Create maps using ArcGIS; learn new company software. |

## 4.2 Skills and Dispositions

At least one skill is mentioned in each ad, and some ads mention 20 or more skills. Four skills appear at least once in >50% of ads: written communication (67%), field skills (63%), planning (53%), and the ability to drive a vehicle (51%) (Table 4). We found no occurrences of interdisciplinary thinking, managing uncertainty, or systems thinking skills—all three of which were identified as critical skills by the sample of geoscience employers represented in *Vision and Change* (Mosher and Keane, 2021).

Skills vary substantially in both the number of ads in which they occur and the total number of times they occur (Figs. 4 and 5, Tables 4–6). Whereas written communication and field skills occur in roughly the same number of ads, the total number of instances of field skills (14,812) is nearly three times the total number of instances of written communication (5906). Quantitative skills and planning skills also commonly appear multiple times within single ads; ads for federal government jobs in particular include quantitative skills multiple times.

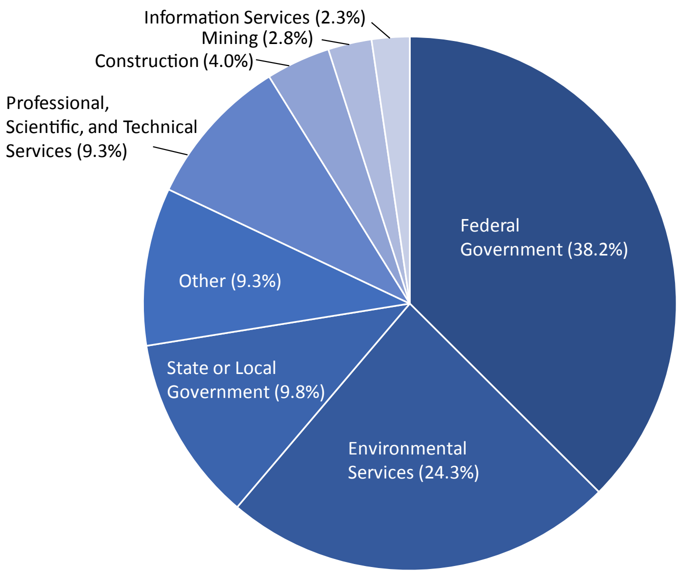


**Figure 1. Pie chart shows the distribution of jobs across industry sectors. The "other" category includes oil and gas (2.0%), testing laboratories (1.9%), 4-year universities (1.2%), utilities (1.1%), manufacturing (1.1%), transportation (0.5%), agriculture (0.4%), other educational services (0.3%), non-profit/NGO (0.2%), finance (0.2%), research institute (0.2%), and K–12 education (0.2%).**

Site assessment and evaluation appear in more ads than any other field skill (25%) except unspecified field skills (29%) (Fig. 5, Table 5). Geologic mapping (5%) and map reading (2%) are infrequently included. Of the 202 ads with geologic mapping included, 109 were for geologist positions primarily in mining (n = 39), environmental services (n = 34), and professional, technical, and scientific services (n = 10).

One or more dispositions occur in 29% of the ads. Attention to detail (the most requested disposition) appears at least once in 21% of the ads—more frequently than half of the workforce skills we coded. Dispositions are usually mentioned at the end of the advertisement, where an employer might describe how an ideal candidate fits the job. For example, one ad reads, "This job is ideal for someone who is hardworking, professional, and dependable."

Clear differences exist in the skills requested by occupation (Table 7). The two most common occupations, environmental scientist and geologist, require proficiency in field skills in 82% and 89% of ads, respectively. In contrast, soil and plant scientist positions requested field skills in only 16% of ads. Similarly, some skills were critical to specific occupations despite their overall low occurrence across all advertisements. For example, temporal understanding was one of the least requested skills (6% of ads); however, 93% of meteorologist positions requested temporal understanding skills, usually in the form of predicting weather patterns over time. For some occupations and industry sectors, it is more common for a single ad to list multiple positions, particularly soil and plant scientists in the federal government. As a result, the skills for soil and plant scientists appear more consistently among these ads. The full data set of skills requested by occupation is available in File S2 (see footnote 1).

## 4.3 Correlation Analysis

Field skills and data collection co-occurred in 46% of the advertisements. A correlation analysis shows strong positive correlations among data collection and field skills as well as field skills and record keeping and documentation

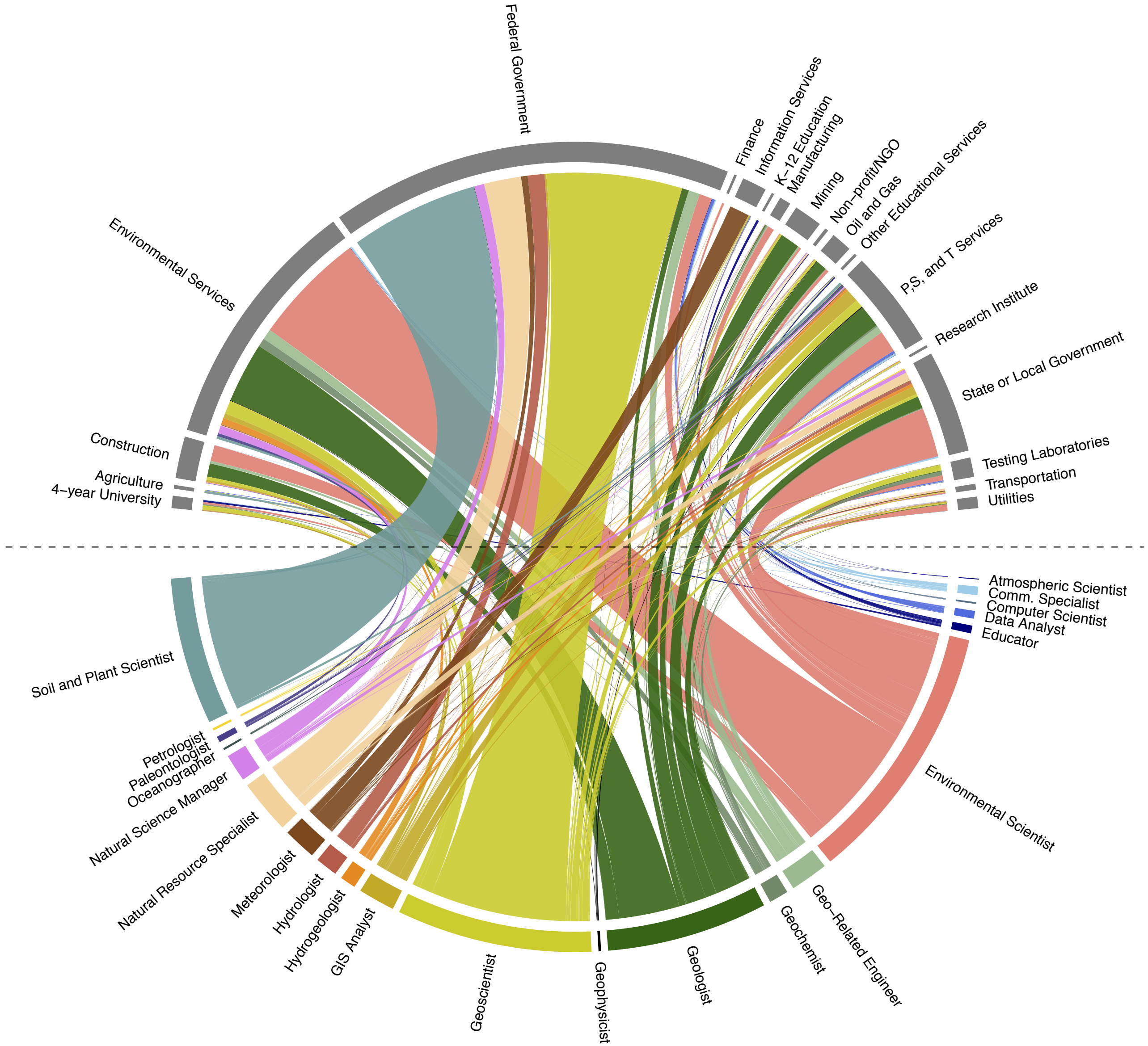


**Figure 2. Chord diagram shows how the occupations represented in the sample of job advertisements (e.g., geologist and environmental scientist; bottom half of the diagram) are distributed among the industry sectors (e.g., the federal government and environmental services; top half of the diagram). Occupations are shown in color below the horizontal gray dashed line, and industry sectors are shown in gray above the dashed line. The size of the outer rim segments reflects the relative proportion of occupations and industry sectors in the sample of job advertisements. The lines connecting occupations and industry sectors reflect how many jobs of a specific occupation were found in each industry sector. For example, soil and plant scientist was the fourth most observed occupation and was almost exclusively found in the federal government sector. P, S, and T—the professional, scientific, and technical services sector.**

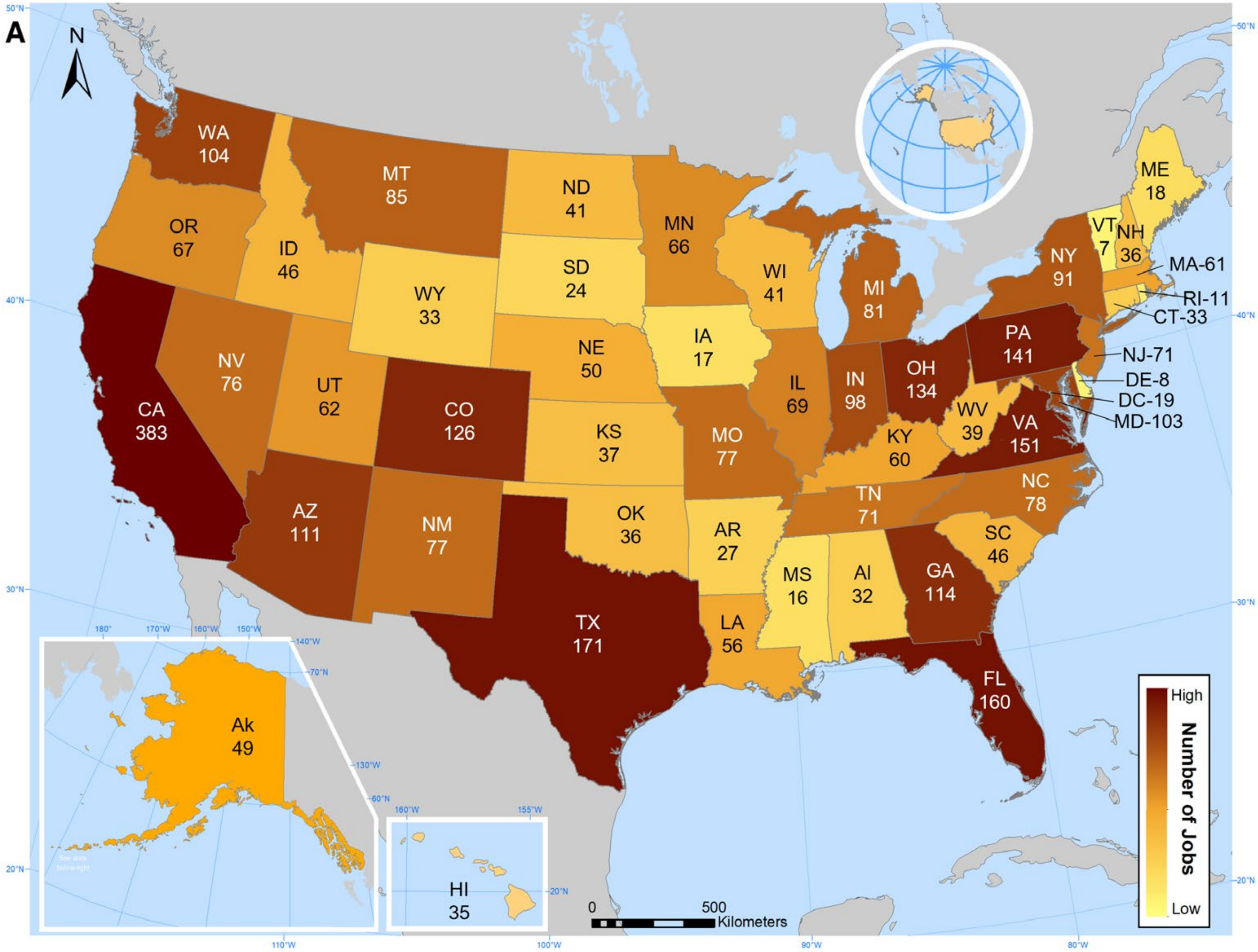


Figure 3. (A) Map shows the distribution of jobs across all 50 states and the District of Columbia. (*Continued on following page.*)

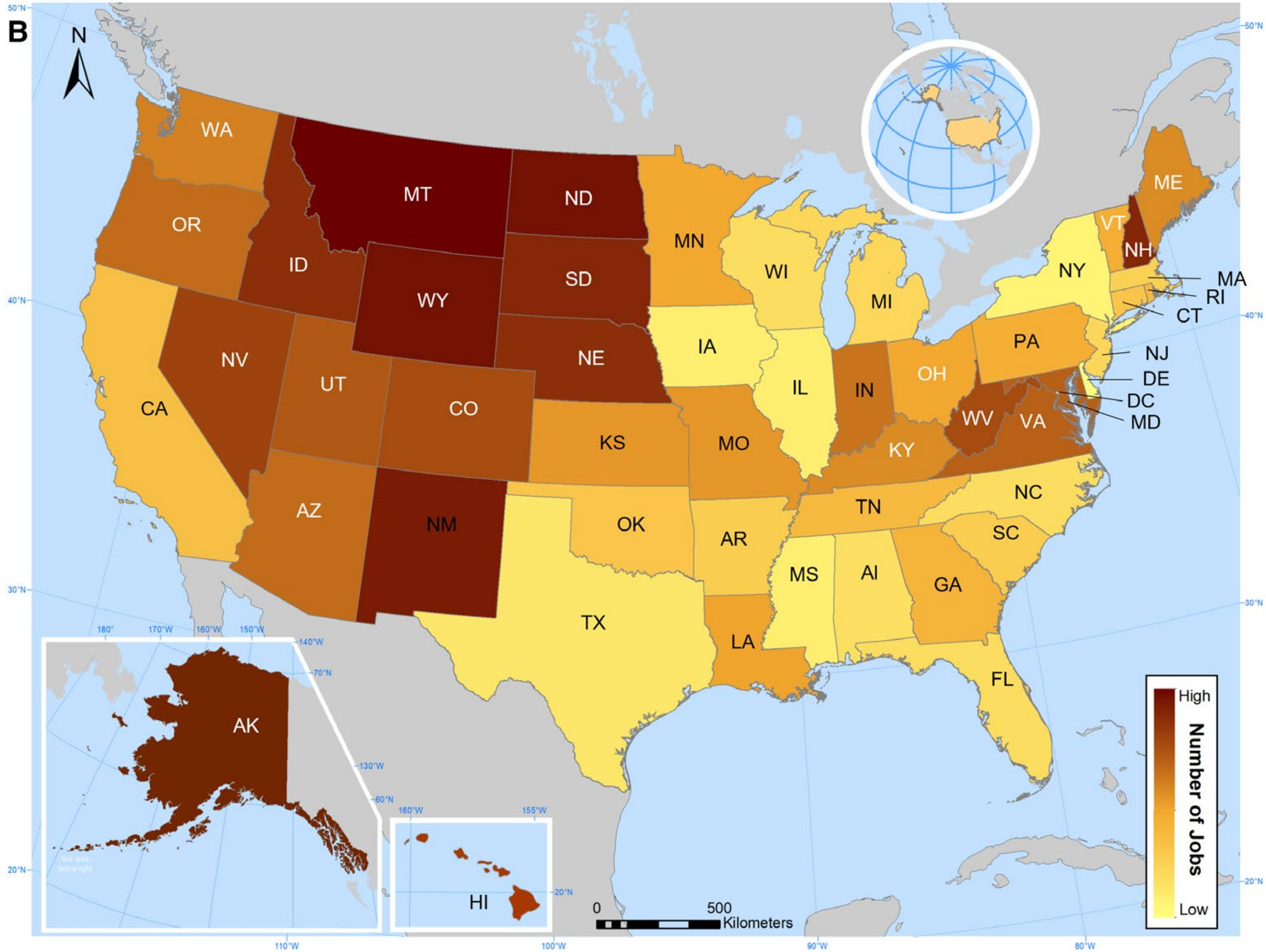


**Figure 3 (*continued*). (B) Map of the distribution of jobs is normalized by state population (U.S. Census Bureau, 2021). Not represented in this figure are jobs advertised in U.S. territories (n = 17; <1%).**

(Fig. 6). There was a strong positive correlation between large data management and quantitative skills. No skills were strongly inversely correlated with each other.

TABLE 4. RESULTS FROM JOB ADVERTISEMENT ANALYSIS

| Skill | Total ads found | Total occurrences |
|---|---|---|
| Field Skills | 2321 (63%) | 14812 |
| Written Communication | 2456 (67%) | 5906 |
| Planning | 1925 (53%) | 5637 |
| Data Collection | 1755 (48%) | 4239 |
| Driving | 1859 (51%) | 3945 |
| Computer Skills | 1334 (36%) | 3568 |
| Data Interpretation | 1263 (34%) | 3375 |
| Physical Abilities | 1123 (31%) | 2973 |
| Quantitative Skills | 828 (23%) | 2950 |
| Oral Communication | 1597 (44%) | 2940 |
| Work as Part of a Team | 1441 (39%) | 2786 |
| Record Keeping or Documentation | 1124 (31%) | 2588 |
| Project Management | 1354 (37%) | 2414 |
| Problem Solving or Critical Thinking | 1188 (32%) | 2179 |
| Customer or Client Relations | 1305 (36%) | 1940 |
| Time Management | 1319 (36%) | 1933 |
| General Communication | 1372 (37%) | 1895 |
| Data Processing | 1200 (33%) | 1699 |
| Spatial Understanding | 749 (21%) | 1672 |
| Equipment Maintenance and Calibration | 693 (19%) | 1334 |
| Large Data Management | 590 (16%) | 1285 |
| Follow Safety Protocols | 558 (15%) | 1132 |
| Attention to Detail | 779 (21%) | 1097 |
| Lab Skills | 453 (12%) | 997 |
| Hazardous Waste and Emergency Response Training | 500 (14%) | 953 |
| Leadership | 647 (18%) | 877 |
| Supervision and Training | 671 (18%) | 826 |
| Work Independently | 535 (15%) | 684 |
| Temporal Understanding | 182 (5%) | 634 |
| Research Information | 248 (7%) | 345 |
| Initiative | 317 (9%) | 343 |
| Desire to Learn | 177 (5%) | 200 |
| Positive Attitude | 159 (4%) | 188 |
| Professionalism | 134 (4%) | 174 |
| Work Ethic | 152 (4%) | 164 |
| Apply Skills in New Scenarios | 127 (3%) | 134 |
| Reporting in the Field | 23 (1%) | 23 |
| Interdisciplinary Thinking | 0 (0%) | 0 |
| Manage Uncertainty | 0 (0%) | 0 |
| Systems Thinking | 0 (0%) | 0 |

## 5 DISCUSSION

### 5.1 Robustness of Sample

The proportions of industry sectors in our sample of job ads are similar to those of Wilson (2019), which suggests that our data set accurately represents job availability across industry sectors. Wilson (2019) found the majority of bachelor-level geoscientists to be employed in the federal government and environmental services sectors, which are the two most frequently sampled sectors in our ads. There is little reason to suspect that any industry sector was over- or under-sampled.

### 5.2 Field Skills

Field skills are the skill set most requested by the employers in our data set (Fig. 4) and the most frequently listed for all occupations except GIS analyst, communication specialist, data analyst, computer scientist, and educator. Field work is embedded in geoscience curricula (Petcovic et al., 2014), and instructors frequently report asking students to make field observations in commonly offered majors-level geoscience courses (Egger et al., 2019; Viskupic et al., 2021). As recently as 2009, nearly all geoscience programs required students to complete a capstone field course prior to graduation (Whitmeyer et al., 2009), but a 2022 study found that only 50% of geology programs require students to complete a field camp course prior to graduation (Klyce and Ryker, 2022). In 2020, prompted by the COVID-19 pandemic and canceling of in-person classes, many programs had to create online or virtual versions of their field courses so that their students could fulfill graduation requirements, and some continue to offer this option (Peace et al., 2021). At the same time, an international group of field instructors defined the learning outcomes for capstone field experiences to determine if the same outcomes can be achieved through both in person and online field courses (Teaching with Online Field Experiences, 2020). Many of the skills listed in these community-defined learning outcomes were frequently requested by employers in this study, such as data collection and interpretation, written and oral communication, teamwork, and planning. Of the field-specific skills analyzed in this study (Table 2), documenting field activities, planning field work, geologic mapping, and field safety were also included in the community-defined outcomes, though these skills were not necessarily the most frequently seen in ads.

The specific skills students are learning and practicing in the field can vary greatly. Students in a field-based hydrology class may spend time retrieving groundwater data from wells and collecting water quality data, whereas students in a field-based structural geology class may spend most of their time practicing geologic mapping. Collecting groundwater data and geologic mapping are both considered field skills but are procedurally and cognitively different; building one skill does not lead to proficiency in the other. The large number of employers requesting field skills indicates that many students are going to be asked to perform work in a field setting upon entering the workforce, regardless of which

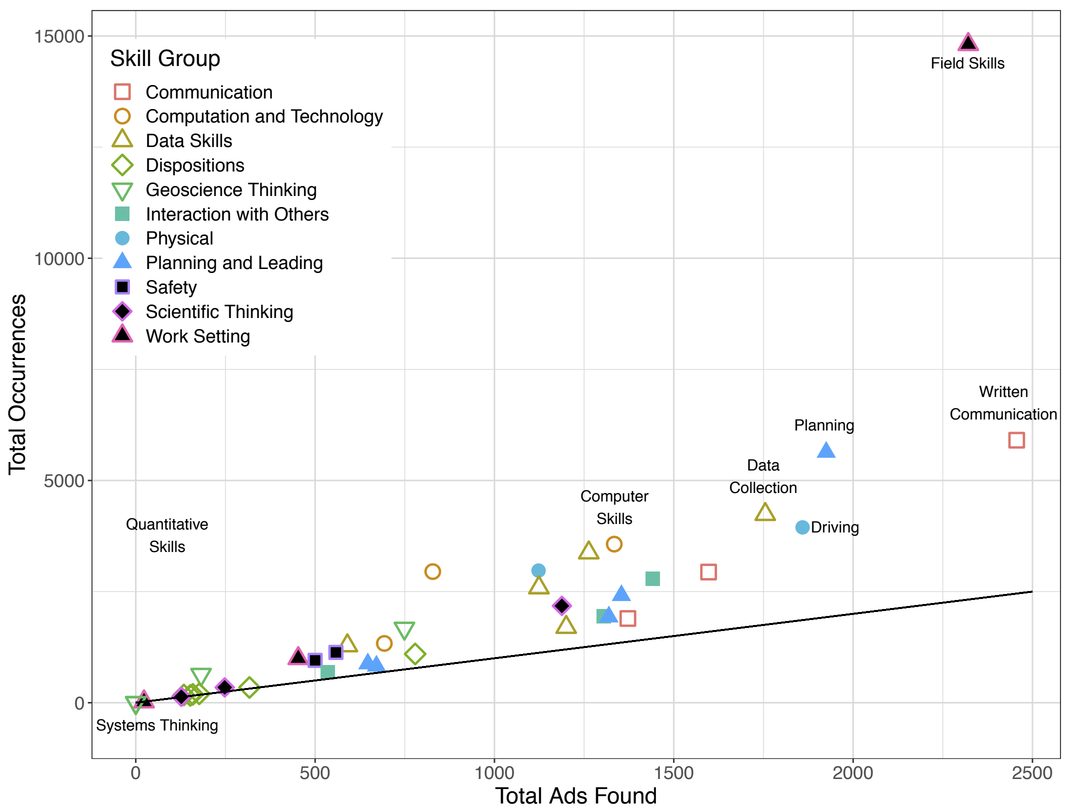


**Figure 4. Scatterplot shows the number of ads in which each skill was observed versus the total number of times each skill was found across all ads. Colors and shapes reflect skill groups (after Viskupic et al., 2021). The black trendline represents a 1:1 ratio (i.e., each skill only occurred once in each ad).**

geoscience career path they choose. Programs may want to assess the field experiences within their curricula to see if students have the opportunity to learn and practice the specific field skills that employers seek, such as site assessments, monitoring, and environmental sampling (Fig. 5). Additionally, data collection and record keeping are highly correlated with field skills in our data set (Fig. 6) and could be similarly integrated in course-based field experiences.

### 5.3 Quantitative Skills

Quantitative skills are commonly practiced in geoscience classes (McFadden et al., 2021; Viskupic et al., 2021) and are focal points for initiatives to increase geoscience student success (Jones and Patino, 2016). Though quantitative skills were requested in only 25% of ads, they are usually mentioned multiple times within these ads. We interpret that skills that occur frequently within a single ad (i.e., skills that fall above the 1:1 correlation line in Figs. 4 and 5) are more highly valued than skills that occur less frequently. Most ads requesting quantitative skills are for federal, state, or local government positions and are evenly distributed among occupations. This suggests that quantitative skills are not necessarily in high demand for entry-level positions but are important for the jobs that request them.

In contrast, the employers who participated in *Vision and Change* identified quantitative skills as one of the most important skills for geoscience undergraduates to have (Mosher and Keane, 2021). One possible explanation for this difference is that employers who participated in *Vision and Change* (Mosher and Keane, 2021) were not exclusively considering entry-level positions, as we are. Although they may not be required for entry-level positions, quantitative skills may be more critical for advancement to higher-level positions. We found a moderately strong positive correlation between quantitative skills and project management skills (Fig. 6), and project management may also be more common in higher-level positions.

Quantitative skills may also be implicit in other skills such as data interpretation, which is far more common in the ads (Table 4) and is positively correlated with quantitative skills (Fig. 6).

### 5.4 Planning Skills

Planning skills are listed in 53% of ads (Table 4) and are commonly mentioned numerous times in single ads, which suggests they are important for the posted positions. Planning skills have been a focus of study in other disciplines such as physiology (Bruthers et al., 2021) and chemistry (Reynders et al., 2019; Picard et al., 2022). In the geosciences, Nyarko and Petcovic (2022) discuss planning skills as a component of teamwork: employers who were interviewed want team members to create efficient task designs and prepare budgets, both of which are components of planning. Although they were not asked about the practice of planning skills in courses, 88% of respondents to the 2016 National Geoscience Faculty Survey reported that their students work as part of a team in majors-level geoscience courses (Egger et al., 2019). We cannot assume that students engaged in teamwork activities are also practicing planning skills, but it is possible that many are. Considering the number of employers requesting planning skills in the ads, geoscience programs may want to highlight or create opportunities for students to learn and practice these skills in their curricula.

### 5.5 Communication Skills

Communication skills are the most sought-after nontechnical skills in the workforce, regardless of education level or degree field (Rios et al., 2020). In our data set, communication skills are the most consistently requested skills across all industry sectors and among all occupations. Unlike field skills, which appear rarely for some occupations, at least one form of communication skills (written, oral, or general) appears in at least 50% of ads for every occupation. Written communication appears most frequently (67% of ads) and is usually in the form of report writing. Oral communication appears in 44% of ads, usually in the form of communication with clients and coworkers. Similarly, employers surveyed in *Vision and Change* (Mosher and Keane, 2021) stress that students need to learn to tailor their communication to their intended audience, including fellow scientists and non-specialists, such as clients and contractors.

Unfortunately, written communication is an essential workforce skill that recent graduates often lack (Moore and Morton, 2017). Program heads and chairs surveyed in *Vision and Change* describe numerous ways in which their students

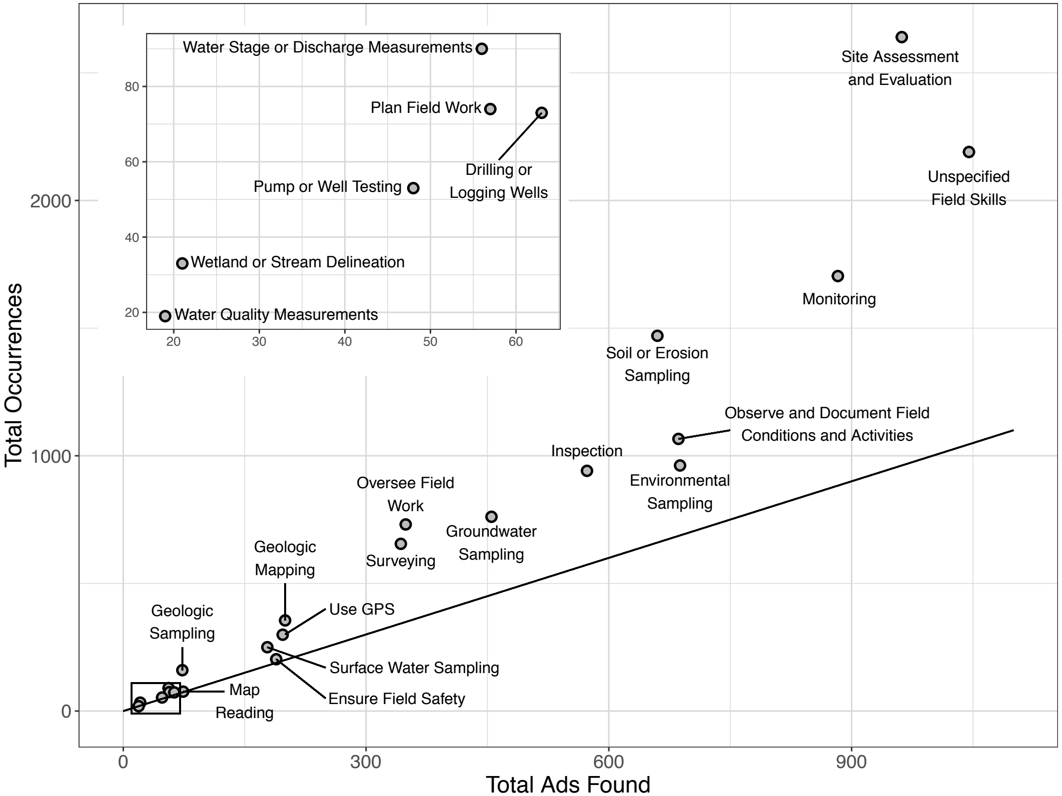


**Figure 5. Scatterplot shows the number of ads in which each field skill was observed versus the total number of times each field skill was found across all ads. The six least requested field skills in are shown in the inset. The black trendline represents a 1:1 ratio (each skill only occurred once in each ad).**

TABLE 5. RESULTS FROM THE FIELD SKILLS ANALYSIS

| Skill | Total ads found | Total occurrences |
|---|---|---|
| Site Assessment and Evaluation | 962 (25%) | 2640 |
| Unspecified Field Tasks | 1045 (29%) | 2190 |
| Monitoring | 883 (24%) | 1704 |
| Soil or Erosion Data | 660 (18%) | 1470 |
| Document Field Conditions and Activities | 686 (19%) | 1066 |
| Environmental Sampling | 688 (19%) | 962 |
| Inspection | 573 (16%) | 941 |
| Groundwater Sampling | 455 (12%) | 761 |
| Oversee Field Work | 349 (10%) | 731 |
| Surveying | 343 (9%) | 655 |
| Geologic Mapping | 200 (5%) | 355 |
| Use GPS | 197 (5%) | 299 |
| Surface Water Sampling | 178 (4%) | 250 |
| Ensure Field Safety | 189 (5%) | 203 |
| Geological Sampling | 73 (2%) | 160 |
| Water Stage or Discharge Measurements | 56 (2%) | 90 |
| Map Reading | 74 (2%) | 76 |
| Plan Field Work | 57 (2%) | 74 |
| Drilling or Logging Wells | 63 (2%) | 73 |
| Pump or Well Testing | 48 (1%) | 53 |
| Wetland or Stream Delineation | 21 (1%) | 33 |
| Water Quality Measurements | 19 (1%) | 19 |

TABLE 6. RESULTS FROM THE COMPUTER SKILL SUB-CODES ANALYSIS

| Skill | Total ads found | Total occurrences |
|---|---|---|
| Basic | 1112 (30%) | 2455 |
| Specialized Software | 469 (13%) | 987 |
| Coding | 88 (2%) | 122 |

practice communicating in written and oral form to scientific and non-specialist audiences (Mosher and Keane, 2021). Seventy-six percent of respondents to the 2016 National Geoscience Faculty Survey reported asking students in majors-level geoscience courses to complete formal writing assignments, and 53% reported asking students to formally present project results in a talk or poster (Egger et al., 2019). Written and oral communication skills are practiced across the most commonly offered majors-level courses, and students are likely to practice these skills multiple times in a degree program (Viskupic et al., 2021). Our work reaffirms the importance of these skills for success in the workforce.

### 5.6 Systems Thinking Skills

Employers surveyed in *Vision and Change* viewed systems thinking as an important skill (Mosher and Keane, 2021), yet none of the ads in our data set listed systems thinking skills. Employers may describe systems thinking skills in a way that our coding scheme does not recognize. When discussing systems thinking skills, employers who participated in the *Vision and Change* workshop noted that applicants should be able to collect data in the field, analyze and interpret the data, and apply their results to solve problems in the context of a dynamic Earth system (Mosher and Keane, 2021)—all skills that we coded for separately (Table 2) and among which we see positive correlations (Fig. 6). Therefore, it may be that the employers sampled in this study do desire systems thinking but communicate this by requesting a collection of other skills that are commonly applied together in a systems approach. As with quantitative skills, it is also possible that systems thinking is a skill expected for higher-level positions but not at the entry level.

### 5.7 Physical Abilities

The ability to drive a vehicle or possess a valid driver's license appears in more than 50% of the ads. Some ads indicated that driving to site locations would be required to perform assigned duties; however, other ads requesting a valid driver's license gave no indication of how driving would play a role in the job duties. This requirement could present a barrier for some students: some international students or students from urban centers may not have a driver's license, and students with physical disabilities that prevent them from possessing a driver's license but are otherwise qualified for the job may not apply.

One or more forms of physical abilities appear in 31% of the ads. These range from carrying 25 or more pounds over short distances to physically demanding hikes across rough terrain in wilderness areas lasting multiple days. Like requests for a driver's license, many of the requests for physical abilities do not appear to align with the essential job functions. For example, in multiple ads, GIS analyst positions list the ability to carry 50 pounds without any indication of why carrying it would be necessary, as all essential job functions listed could be completed with a computer. Physical abilities are often listed at the end of ads, and the statements in different ads from the same employer are often identical, which suggests that the statements are included regardless of the specific needs for the job. Furthermore, statements of accommodations are not provided, which makes these physical requirements seem essential.

Though the ability to drive and occasionally lift 50 pounds may seem like innocuous statements to many, requiring these skills could discriminate against otherwise qualified applicants if they are not aware that the law requires accommodations to be made (U.S. Department of Health, Education, and Welfare, 1978). We encourage programs to help raise students' awareness of the Americans with Disabilities Act and that physical abilities should not be a limiting factor for most jobs.

### 5.8 Dispositions

Compared to many of the workforce skills discussed, dispositions appear less frequently but were common enough to be included in our study. Faculty in undergraduate geoscience programs may be less familiar with how

TABLE 7. MOST FREQUENTLY REQUESTED SKILLS IN THE MOST COMMON OCCUPATIONS

| Skill | Environmental Scientist (number [n] = 914) | Geologist (n = 561) | Geoscientist (n = 680) | GIS Analyst (n = 129) | Meteorologist (n = 115) | Soil and Plant Scientist (n = 513) |
|---|---|---|---|---|---|---|
| Written Communication | 77% | 79% | 59% | 49% | 59% | 80% |
| Field Skills | 82% | 89% | 62% | 50% | 29% | 16% |
| Data Collection | 60% | 83% | 51% | 33% | 22% | 8% |
| Oral Communication | 53% | 50% | 46% | 36% | 40% | 10% |
| Computer Skills | 51% | 51% | 14% | 95% | 13% | 7% |
| Project Management | 48% | 40% | 51% | 40% | 15% | 9% |
| Work as Part of a Team | 50% | 56% | 22% | 54% | 56% | 4% |
| Driving | 52% | 59% | 18% | 30% | 20% | 84% |
| Planning | 43% | 44% | 51% | 42% | 19% | 94% |
| Data Interpretation | 41% | 49% | 25% | 67% | 45% | 8% |
| General Communication | 42% | 37% | 11% | 26% | 23% | 85% |
| Problem Solving or Critical Thinking | 39% | 31% | 44% | 34% | 23% | 4% |
| Record Keeping or Documentation | 38% | 50% | 16% | 31% | 20% | 6% |
| Customer or Client Relations | 37% | 30% | 8% | 28% | 22% | 89% |
| Time Management | 34% | 20% | 39% | 29% | 61% | 72% |
| Quantitative Skills | 23% | 19% | 20% | 33% | 30% | 7% |
| Data Processing | 23% | 36% | 14% | 73% | 6% | 85% |
| Physical Abilities | 26% | 29% | 10% | 13% | 6% | 74% |
| Large Data Management | 19% | 19% | 9% | 75% | 3% | 3% |
| Spatial Understanding | 15% | 38% | 11% | 81% | 0% | 6% |
| Temporal Understanding | 1% | 1% | 6% | 1% | 93% | 0% |

to teach dispositions than they are with how to teach other skills, but we can learn from other disciplines. For example, teacher preparation programs systematically integrate dispositions into curriculum and evaluate students on their professional dispositions (Katz and Raths, 1986). Not surprisingly, Beverly et al. (2006) found that simply providing students with a list of dispositions is not enough, but having students develop examples and non-examples of dispositions clarified what dispositions are and look like. Similarly, Berkling et al. (2019) used a project-based teaching environment to introduce dispositions and asked students to reflect on which dispositions they excelled in and which needed improvement. Students in the study frequently identified initiative as the disposition in most need of improvement (Berkling et al., 2019). Initiative was also identified in this study as important to employers.

Incorporating the teaching of dispositions into geoscience programs takes deliberate effort. Both course-level and program-level learning outcomes can be developed that emphasize dispositions such as professionalism, and the community-developed learning outcomes for capstone field experiences provide a good example; students should be able to demonstrate behaviors expected of professional geoscientists (Teaching with Online Field Experiences, 2020).

### 5.9 Geographic Distribution of Jobs

The geographic distribution of jobs represented by the ads we sampled (Fig. 3A) closely matches the distribution of geoscience programs across the United States (Wilson, 2019). Considering that some employers partner directly with geoscience programs to recruit employees, it may be advantageous for students to join geoscience programs in areas of the United States where they hope to gain employment. However, if students are willing to travel, resource-rich states, such as Wyoming and Montana, could provide a less competitive job market given the number of geoscience jobs per capita in those states (Fig. 3B). Additionally, geoscience programs may want to consider the competitiveness of the local or regional workforce that their graduates will encounter. For example, to increase recruitment and retention of students, Mosher and Keane (2021) suggest that programs engage directly with prospective students and their families about the benefits of a geoscience career to their local community. Programs in states with a high number of jobs per capita could promote a less competitive job market to recruit and retain students from local communities.

## 6 SUMMARY AND IMPLICATIONS

Our data set provides insight into entry-level geoscience jobs that is useful for departments and programs in designing and updating their curricula and in advising students. Our analysis identifies skills that bachelor-level geoscientists will need to enter the workforce across sectors, industries, positions, and geography. Across all jobs, field skills, written communication, planning, and data collection are in high demand by employers. Specific field skills, such

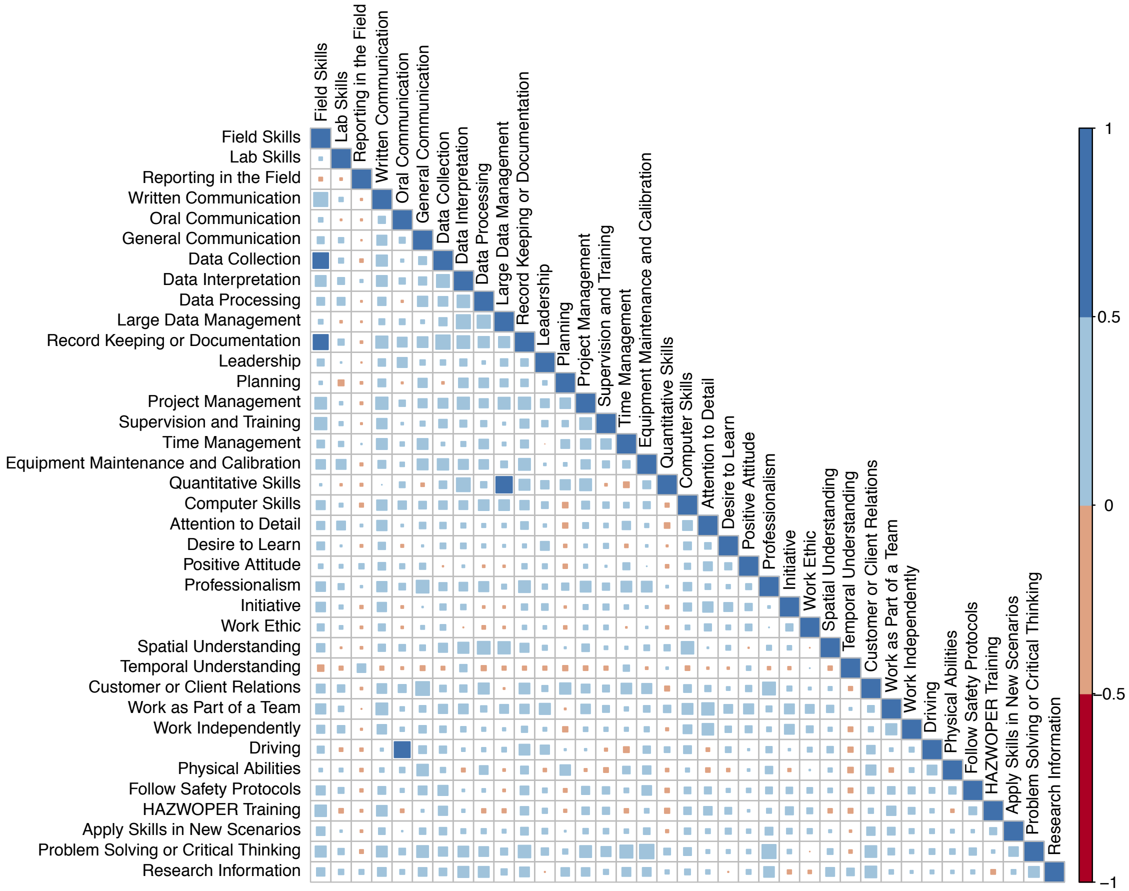


**Figure 6. A correlation analysis of skills and disposition codes is plotted. The size of the square represents an absolute correlation measurement. For example, a large square from the 0–0.5 color range would represent a correlation closer to 0.5 while a small square in the same range would be closer to 0.**

as site assessment and evaluation, monitoring, and soil erosion sampling appear frequently. Many employers seek applicants with dispositions such as attention to detail.

Departments and programs can make use of these data to review their curricula and co-curricular activities in light of making students aware of employer expectations and helping students develop the skills they need to enter the workforce. One way to raise students' awareness and motivate their learning is to simply be explicit in connecting their course activities, the skills they are developing, and the skills they are likely to need in the workforce. The Transparency in Learning and Teaching (TILT) project (Winkelmes, 2013, 2014) provides an assignment template that specifically asks faculty to articulate the purpose of an assignment and to describe the skills and knowledge students will gain by completing the assignment. Using such a template can help students to see the value of their work and can help instructors be purposeful in their lesson design.

Departments may also consider revising some of their courses or activities to give students more practice with skills expected for entry-level positions. When providing field work opportunities to students, programs could consider activities that reflect the types of field work students will encounter in entry-level positions, such as site assessment and evaluation and prolonged monitoring techniques. Additionally, programs may want to consider how to introduce dispositions into the curriculum and allow students sufficient time and opportunity to reflect on their development.

Importantly, students also need to be able to demonstrate or document their competencies in job applications. Explicit connections between course work and job skills could help them do so, as could activities in which students practice describing how they meet a set of qualifications through the work they have done.

While our results encompass a broad range of geoscience employers, a geoscience degree can be used in many ways, and the skills we highlight may not be needed by all bachelor-level graduates. In addition, we acknowledge that these results are a snapshot of an evolving workforce, and they provide a baseline for future work. Periodic collection and coding of ads would capture the changing expectations of employers and job availability. Our study provides an important step in understanding workforce needs, and in helping programs prepare bachelor-level geoscientists for the workforce.


## ACKNOWLEDGMENTS

The authors state that they have no conflicts of interest with respect to the results of this work. We also acknowledge funding provided by National Science Foundation award DUE-1742215 and by National Science Foundation/Geological Society of America Graduate Student Geoscience Grant #1949901.


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