

## 1 Introduction

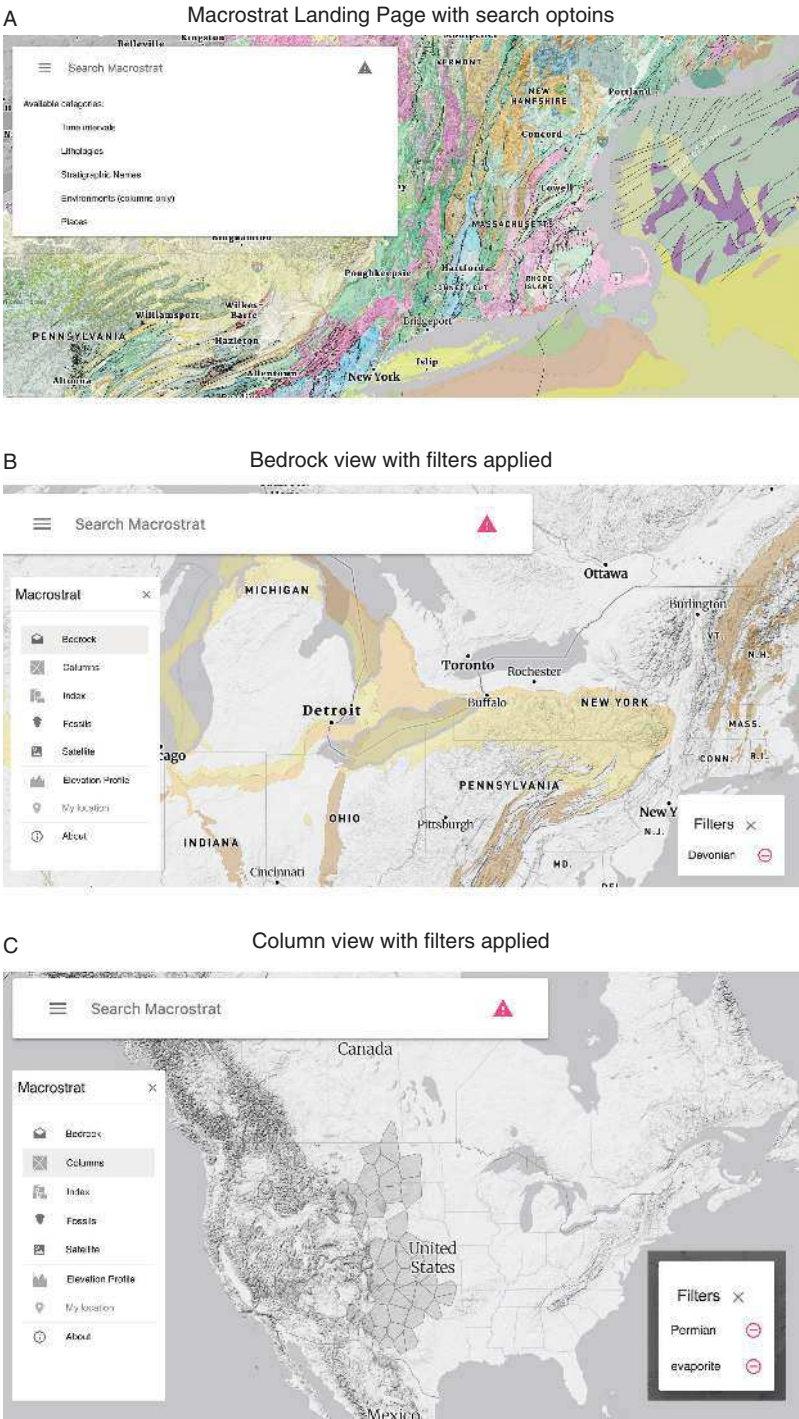
### 1.1 What Are Macrostrat and Rockd?

Macrostrat ([macrostrat.org](http://macrostrat.org)) is a platform for the aggregation and dissemination of geological data relevant to the spatial and temporal distribution of sedimentary, igneous, and metamorphic rocks (Peters et al., 2018). Interactive applications built upon Macrostrat data and infrastructure are designed for educational and research purposes. Several applications that use Macrostrat-sourced data now exist, including the third-party Flyover Country app ([fc.umn.edu](http://fc.umn.edu)) and Rockd, developed by Shanan Peters and the Macrostrat group at the University of Wisconsin Madison. Rockd is a mobile app and complementary web-based portal designed to facilitate the collection and use of field-based geological observations of all types. Rockd allows users to post geolocated text and image content to a database that is linked to a wide range of geological entities, including bedrock map units, lithostratigraphic rock units, lithologies, fossil taxa, and minerals.

The Macrostrat database's web application allows users to access information on both surficial geology (bedrock) and stratigraphic (column) data (Fig. 1). The bedrock view allows users to examine a dynamic global geological map of surface units, search for specific locations and lithologies, and pull up additional information on map units (Fig. 1B,D). The column view allows users to examine regional geology at a stratigraphic level (Fig. 1C). Column data are most comprehensive for North America, but additional regions such as New Zealand are now available as well. Clicking on a column polygon reveals the stratigraphy of the area, links to Paleobiology Database collections, and shows information on lithology types, literature references, and more. Macrostrat allows users to search for a particular lithology type, stratigraphic unit, or time period, and allows merged searches (e.g., searches for all columns that contain Cambrian carbonates). The broader Macrostrat dataset has been used extensively for research purposes (i.e., Finnegan et al., 2012; Peters and Gaines, 2012; Nelsen et al., 2016; Husson and Peters, 2017); however, this is the first publication to focus on educational applications.

Rockd is a mobile app based on the Macrostrat dataset. Although the app can be used to explore the global bedrock map interface of Macrostrat, its primary utility lies in the use of geolocation technology. By simply opening the app, a user is presented with Macrostrat's "best guess" for the geological unit the user is currently standing on, its age, lithology, and, for rocks younger than 600 million years, the reconstructed paleogeography for that location at the time the rock formed (Fig. 2). In addition, the map interface shows locations, most with photos that other users have uploaded of nearby outcrops (Fig. 3).

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**Figure 1.** Macrostrat overview. A, Main Macrostrat landing page showing the search bar with options. B, Macrostrat bedrock view showing surface

Search Macrostrat

23.36E7 43.772N 133m | 338m

**Original map**

**Name:** Michigan Formation

**Age:** Mississippian (359.9 - 323.2Ma)

**Stratigraphic name(s):** Michigan Formation

**Lithology:** Major: shale; Minor: black shale, incidental: sandstone, dolostone, limestone, arthysite, gypsum

**Comments:** Secondary unit description from USGS Geologic Names lexicon (ref. M1016): Unit, which is mostly shale, is Osagean and Meramecian in age and conformably overlies the Marshall Sandstone. Underlies the Meramecian Bayport Limestone. Underlies Michigan Formation re...

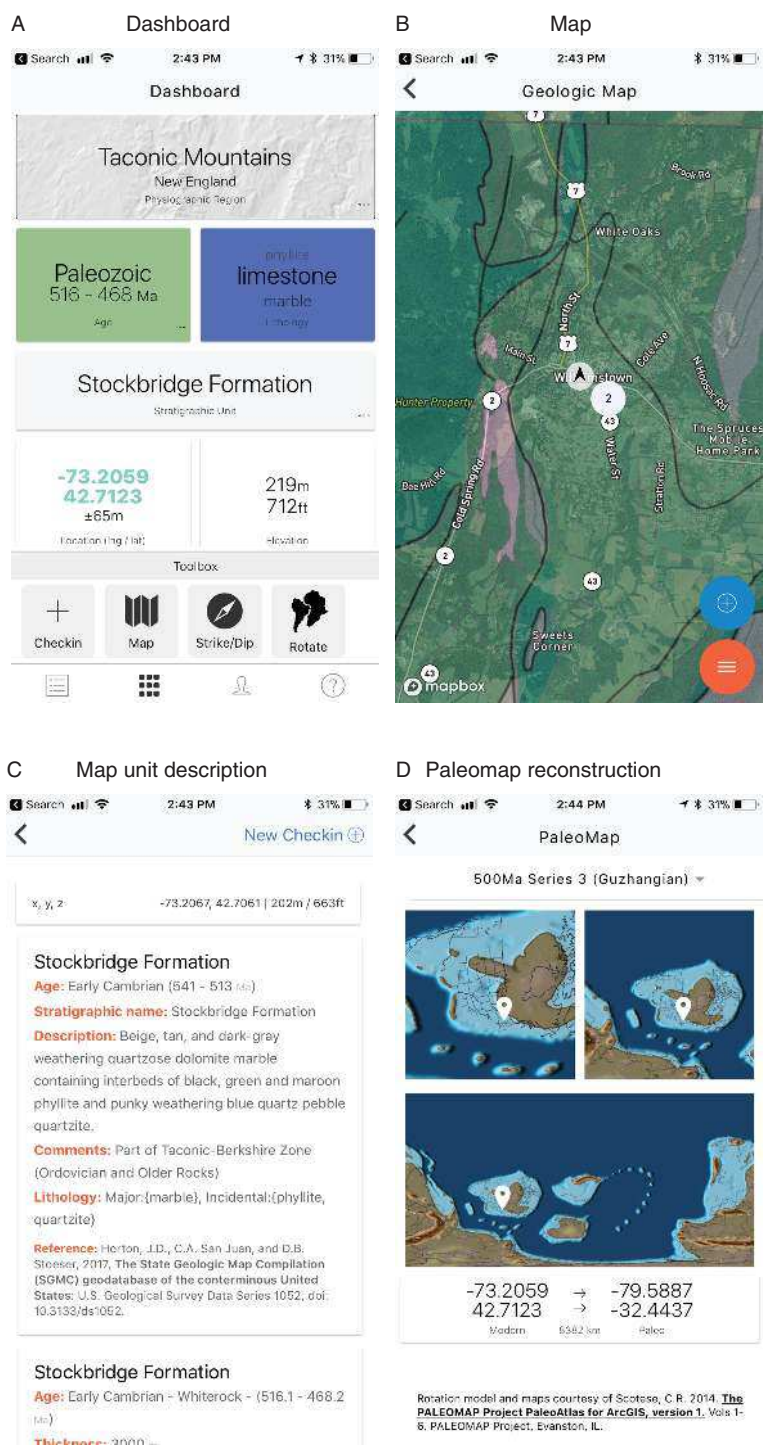
Source: I-416, I.E., C.A. San. 1978, p. 8-9. D. 56000; 2317. The State Geologic Map Completion (SGMC) geodatabase of the open-source United States Geological Survey (USGS) data.

The screenshot displays the 'Fossil Collections' interface. On the left, a map of Ontario, Canada, is shown with a search bar at the top containing the text 'Search Macrostrat'. The map features various locations marked with white dots, representing fossil collection sites. On the right, a sidebar titled 'Fossil Collections' provides details for a specific collection. The sidebar includes a search bar and a list of collections. The collection details shown are:

- Name:** Thayer Peabody Collection A9162a
- Collection no.:** 96380
- Age:** Gteland (362.7 - 382.7u)
- Group:** Tully
- Formations:** Tully
- Lithology:** lithified siltstone
- Environment:** air-laid mud

Below the collection details, a 'References' section lists several publications related to the collection, including works by Thayer (1960), Thayer and Peabody (1960), and Thayer and Peabody (1961).

geological units. Left inset shows layer options that can be viewed by clicking on the three horizontal bars in the search box. Right inset shows that a timescale filter has been applied, so only Devonian-aged rocks are displayed. Clicking on the small triangle in the search box displays applied filters. C, Macrostrat column view with two filters applied. Each polygon is clickable to reveal information about that geological column. D, Macrostrat column and bedrock filters. Sidebar shows information on the map unit represented by the place-marker pin; scrolling down on sidebar will also show information on column stratigraphy. E, Macrostrat bedrock view with Paleobiology Database collections layer added. Clicking on an individual circle will pull up a sidebar with data on that specific PBDB collection.



**Figure 2.** Example of Rockd interface. A, Main Rockd app dashboard, showing geological detail of user's current location. B, Dynamic geological



Rockd also has a complementary web-based portal (Fig. 4), without geolocation capabilities, that allows users to browse and search checkins for specific stratigraphic units, lithologies, and time periods.

## 1.2 Why Use These Resources in the Undergraduate Classroom?

Scientific data are increasingly moving into the digital realm, and new technologies enable better access to these data by both professionals and the general public. At the same time, STEM (Science, Technology, Engineering and Mathematics) pedagogical research strongly supports the use of primary data in classroom settings (e.g., Styers, 2018). Thus, digital repositories of scientific data are an exciting and accessible way to bring authentic science into the classroom. However, significant barriers can exist in terms of data access, the challenges of using available analytical tools, and instructor familiarity. Our goal here is to showcase how Macrostrat and Rockd can be used in an undergraduate educational setting, thus reducing barriers for course instructors and enabling more students to interact with primary geological datasets.

### 1.2.1 Providing the Context for Fossil Data

Both Macrostrat and Rockd integrate fossil data, either from the Paleobiology Database or from individual observations in the field. Both also explicitly focus on the temporal and spatial distribution of rocks, and thus are valuable as tools to help students understand the sedimentary record and the fossils that sedimentary rocks contain. In addition, conceptualizing the distribution of different types of rocks through space and time is a key way to understand how environments, climate, and tectonics have changed through time – factors that play critical roles in the patterns of biotic change documented throughout the Phanerozoic.

### 1.2.2 Mobile Learning

Mobile learning is becoming a more and more integral part of teaching and learning, especially in disciplines with place-based aspects, such as the geosciences. Examples of research on mobile learning using smart phones and other

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#### **Caption for Figure 2.** (cont.)

map of user's location. C, Geological map unit information available when user clicks on a map unit on the map screen. D, Paleogeographic reconstruction of user's location at time of bedrock deposition/formation.

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devices show that they can add an important and welcome dimension to student learning experiences (McGreen et al., 2005; Elkins, 2009; Taleb and Sohrabi, 2012; Gikas and Grant, 2013; Dennen and Hao, 2014). Rockd is the most sophisticated mobile learning tool currently available for the geosciences. In addition to allowing students access to geological data, Rockd connects students to an international community of both professional and amateur earth scientists. This is a compelling way to empower students, as they can create their own accounts, make their own checkins, and contribute to a crowd-sourced database of geological knowledge. These attributes make Rockd an example of effective mobile learning, characterized by Gikas and Grant (2013) as learning that (a) engages learners with constant connectivity, (b) fosters collaboration, and (c) enables authentic learning on the move. One of the additional powerful aspects of Rockd is that it allows for informal learning to occur outside of class time. Once students become familiar with the app, they can use it at any time – during breaks, on vacation, on field trips for other courses, or simply during their day-to-day lives. This bridges the gap between the classroom and the “real world” in a powerful way. Thus, Rockd can serve as a link between formal and informal learning environments (Gikas and Grant, 2013).

### *1.2.3 Field, Research, and Active Learning Experiences Increase Retention*

Research indicates that field and research-based experiences have a positive impact on geoscience major recruitment and retention (e.g., Elkins et al., 2018). However, these types of experiences can often be hard to implement, due to cost, logistics, and the inaccessibility of research tools (Bursztyn et al., 2015). In addition, students with disabilities may not be able to fully participate in field-based activities. While Rockd as a mobile app requires that the user is able to go to physical outcrops, the Macrostrat and Rockd web portals do not. As such both are valuable tools to use for students who may not be able to physically participate in field trips (Carabajal et al., 2018), or for faculty who do not have the financial resources or logistical ability to take students into the field. In addition, active, inquiry-based learning and student research opportunities have been shown to increase student interest in STEM and to help increase the retention of traditionally underrepresented groups (Rissing and Cogan, 2009; Graham et al., 2013; Linn et al., 2015; Ballen et al., 2017). This is especially critical in the geosciences, which has the least diverse student population of all the STEM fields (National Center for Science and Engineering Statistics, 2015; Huntoon et al., 2018). Thus, we hope that instructors will find that incorporating Macrostrat and Rockd into

their undergraduate earth science curriculum is a fruitful experience for both faculty and students that increases access to authentic earth science experiences. See Lockwood et al. (2018), for more background on the value of research experiences and active learning in geoscience education.

## 2 How to Use Macrostrat and Rockd

### 2.1 Macrostrat

Macrostrat is available as a web portal at [macrostrat.org](http://macrostrat.org). The landing page is a dynamic geological map showing bedrock and topography. Clicking anywhere on this map will pull up information on the bedrock map unit including unit name, lithology, age, relevant literature references, and more (Fig. 1D). The search bar can be used to search for geological units, time periods, lithology, and for column view, environment (Fig. 1A). The menu bar popup allows users to add or subtract layers of data (Fig. 1B, C, D). For example, by adding *Column* view, polygons that encompass regional stratigraphic data are overlain onto the bedrock map (Fig. 1C, D). Information on these stratigraphic units can be viewed by clicking on “Match basis” names under the Macrostrat category in the information sidebar. Users can also overlay Paleobiology Database collections (*Fossils*; Fig. 1E) and satellite image data (*Satellite*).

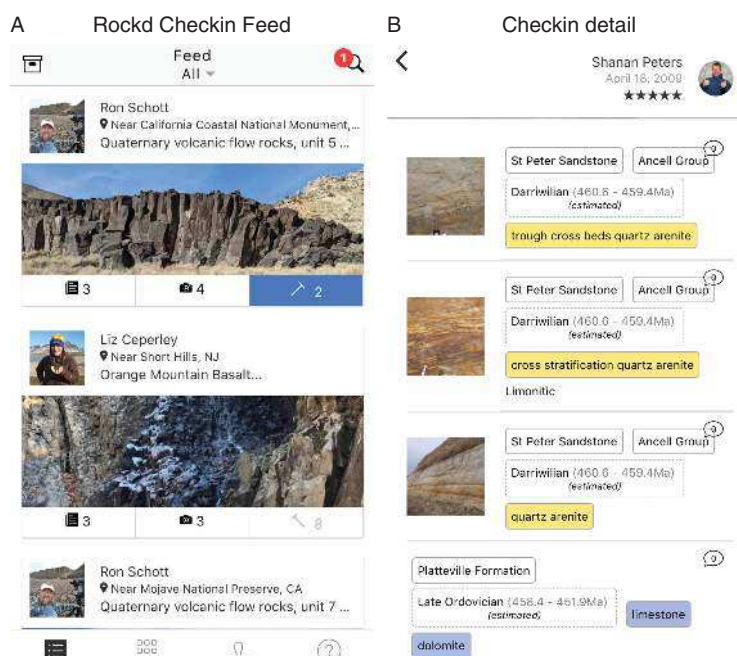
### 2.2 Rockd

Rockd is an app available for download on both the iOS and Android platforms at [Rockd.org](http://Rockd.org) (Fig. 2, Fig. 3). There is also a web-based portal for exploring Rockd checkins and data available at [Rockd.org/explore](http://Rockd.org/explore) (Fig. 4). When a user opens the app, the first thing they will see is a landing page that shows them geological information on their current location (Fig. 2A). This information will usually include the age of the rocks the user is standing on, the name of the geological unit, the user’s current latitude and longitude, their current approximate elevation, and the lithology of the rocks the user is standing on. The accuracy and precision of the estimates vary geographically depending on the available geological map and Macrostrat column coverage. From here, the user can click on the *Map* icon (Fig. 2B), which will show the user a satellite view of their current location with geological map units superimposed on top. By clicking on any of these map units, the user can pull up more information describing the rock unit, most of which derives from the original map sources (Fig. 2C), which are also accessible by clicking on the reference. From the landing page, clicking on the *Rotate* icon (“rotate” is the name of the spherical geometric computational operation that is used to calculate a paleoposition)

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will produce paleogeographic map reconstructions of the user's current location at the time the rocks the user is standing on were formed or deposited (Fig. 2D). By clicking on the *Checkin* icon on the landing page, users can create their own checkin at their location by taking an image of an outcrop, adding a description, and selecting other factors such as lithology. From this page, clicking the camera icon will allow users to take a photo, or select a pre-existing photo, to associate with the checkin. Users can then provide additional information about the location, including a description of the location, a "rating" of 1 to 5 stars, and a tag for other defined attributes such as lithology, structures, fossils, minerals, and more. Once a checkin is created by a user and synced with the Rockd server, it acquires a unique URL that can be shared with anyone who has a web browser. Rockd provides a copy button that allows users to easily paste the URL into a social media post, assignment, or email.

Rockd also allows users to browse through public checkins by others that show images of rock outcrops along with additional information on locality, lithology, and other features (Fig. 3). From any page on the app, users can click



**Figure 3.** Example of a Rockd app checkin. A, Rockd app feed showing a list of checkins. B, Rockd app checkin detail showing additional images, lithological information, and more.



on the *feed* icon in the lower left-hand corner of the app screen (bulleted list icon), which will then pull up a list of checkins with images that users can scroll through (Fig. 3A). From here, users can click on a checkin to get more information and see additional images (Fig. 3B). Geolocated to a geological map, these checkins also provide information on the geological map unit, and can link users to additional information. One of the unique aspects of the Rockd app is that it allows interactions among users. A user can “like” another user’s checkin and see who has “liked” their own checkins. Users can also comment on others’ checkins, thus allowing for engagement and communication between users. Rockd also has a web-based application in which users can search and scroll through checkins ([rockd.org/explore](http://rockd.org/explore); Fig. 4).

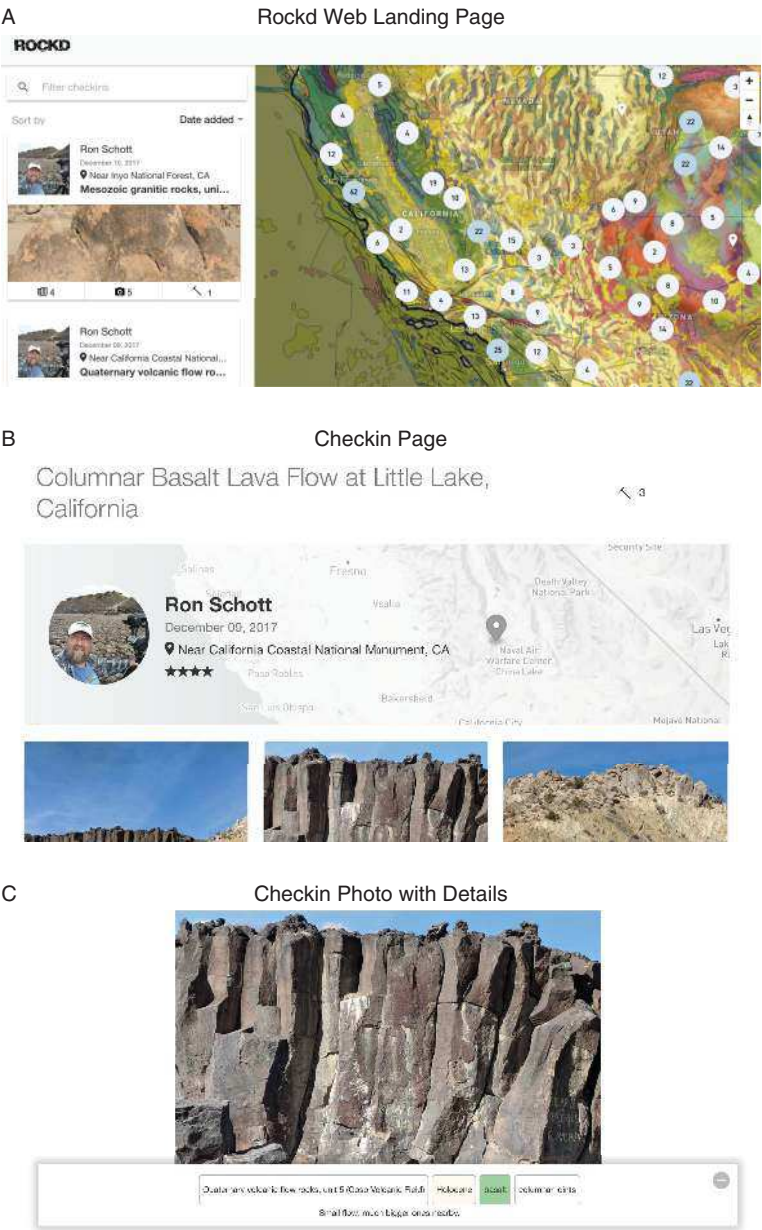
### 3 Educational Integration: Examples and Ideas

As the Macrostrat web application and Rockd mobile app are relatively new tools that are still under active development, the community has not yet created established reviewed educational products. Instead, this section will provide a number of strategies for incorporating Rockd and Macrostrat into different types of earth science classes. Some of these examples are more detailed, while others are intended to serve as starting points for the reader’s adoption.

#### 3.1 A Note on Accessibility

We have tried to present a variety of activity ideas based on accessibility. Rockd mobile requires the use of a smartphone. While many students have access to these devices already, some do not, and we do not wish to highlight economic disparities amongst students. Many activities require that students be able to access local outcrops either on foot or with a vehicle. This may not always be possible, and may be limited by student resources. Likewise, Rockd checkins in the field require the use of a student’s personal wireless data, though we note that images and notes can be taken in the field and checkins uploaded back on campus where free WiFi is more likely to be available. In addition, offline maps can be downloaded before embarking on a field trip. We have also included activities that require only the use of a laptop or desktop computer and access to the Internet, and do not require a smartphone or access to a personal vehicle.

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**Figure 4.** Rockd web application. A, Landing page showing map with checkin counts in circles and checkin feed. B, Example of checkin overview. C, Example of checkin photo with additional details.