GEOGULF2021
AUSTIN
October 27–29, 2021

Integrating Digital and Traditional Field Methods into Geologic Mapping: An Example from Central Texas

Brian B. Hunt[1], Jeffrey G. Paine[1], C. M. Woodruff, Jr.[1], and Mark A. Helper[2]

[1]Bureau of Economic Geology, Jackson School of Geosciences, University of Texas at Austin, Austin, Texas 78758

[2]Jackson School of Geosciences, University of Texas at Austin, Austin, Texas 78758

ABSTRACT

Detailed geologic maps are critical for activities related to energy, minerals, groundwater, hazards, infrastructure, and earth science research as well as teaching. The Bureau of Economic Geology, as the State Geological Survey of Texas, has produced geologic maps for over 100 years. With more than 90% of the state unmapped at 1:24,000 scale, there is opportunity to produce original or compile analog geologic maps using an integrated digital and traditional mapping approach. Geologic mapping has evolved over the last 30 years due to Global Positioning Systems (GPS), Geographic Information Systems (GIS), digital elevation data (lidar), and smart phones. Modern geologic maps are geospatial databases that contain standardized and detailed attributes and metadata for line, point, and polygon features. These features can be stored, shared, symbolized, queried, analyzed, and presented in GIS.

A recent approach to geologic mapping of the Grit Quadrangle (Mason County) illustrates the integration of standard geologic field methods with evolving technologies and data, and the new GIS geologic map database schema (GeMS) prescribed by the U.S. Geological Survey. A preliminary geologic map of this quadrangle was created in GIS using existing maps, orthophotos, and especially the digital elevation models derived from lidar, which can be used to create shaded relief bare-earth models. Field work was iterative with GIS and helped verify the map, identify problem areas, and test hypotheses. Digital field data were collected with a smart phone mapping application and traditional field tools such as Brunton compass, hammer, hand lens, and field notebook. The GIS map database follows the GeMS schema, and an Open-File Map (PDF) was constructed with standard

Hunt, B. B., J. G. Paine, C. M. Woodruff, Jr., and M. A. Helper, 2021, Integrating digital and traditional field methods into geologic mapping: An example from Central Texas: GeoGulf Transactions, v. 71, p. 141–148.

graphics software. The resulting geologic map and accompanying geospatial database will support continued research on earth resources. The approach serves as an evolving model for future geologic mapping.

INTRODUCTION

Geologic maps are critical for activities related to energy, minerals, water, hazards, infrastructure design, and earth science research (Bernknopf et al., 1993). The Bureau of Economic Geology, as the State Geological Survey of Texas, has produced geologic maps for over 100 years. These maps include the Geologic Atlas of Texas comprised of 38 geologic map sheets at a scale of 1:250,000 published in the 1980s. Only about 7% of the 1:24,000 topographic quadrangles in Texas have been mapped at that detail, compared to about 20% for the entire lower 48 states area (Thompson, 2021). Critical earth science activities require detailed geologic maps at the scale of 1:24,000 to 1:100,000, therefore there is a need for continued detailed geologic mapping in Texas.

Geologic mapping at the national level was programmatically renewed by the National Geologic Mapping Act of 1992, which mandated development of the National Cooperative Geologic Mapping Program (NCGMP). STATEMAP is a competitive Federal grant matching program for States, administered by the U.S. Geological Survey (USGS) to produce geologic maps. Since 1996 the Bureau has participated with STATEMAP matching funds provided by the State of Texas Advanced Resource Recovery (STARR) program and the Jackson School of Geosciences. The program first developed the National Geologic Map Database and catalogue (https://ngmdb.usgs.gov/ngm-bin/ngm_home.pl), a collaborative effort of the USGS and the Association of American State Geologists (AASG). The second phase developed a standardized database design for the delivery of geologic maps, known as the Geologic Mapping Schema or "GeMS" (GeMS, 2020). The current phase of the program supports production of new digital maps and seamless compilation maps that follow GeMS.

This paper provides an example of an approach to geologic mapping in Central Texas that uses standard geologic field methods (Compton, 1985) with new technologies and associated map database methods (GeMS, 2020).

Setting

This paper focuses on the recent mapping in the Grit Quadrangle located in northwestern Mason County area of Central Texas and part of the Llano Uplift geologic province. The work involves new detailed (1:24,000) geologic mapping to be published in the fall of 2021 and is part of the STATEMAP program. The area was originally mapped by Virgil Barnes (Barnes and Schofield, 1964) at a planimetric scale of 1:65,000. In addition, parts of the quadrangle contain detailed geologic mapping by Le (1993). Ages of the dominant bedrock units are Precambrian, Cambrian, and Cretaceous. Late Paleozoic normal faults cut Paleozoic and older units. The Mesoproterozoic units are variably deformed and contain multiple generations of ductile fabrics and structures. Surface geologic units include Quaternary alluvium and terrace deposits along streams.

METHODS

Geologic principles (laws) applied to making geologic maps have not changed in the last hundred years. Similarly, standard field methods have changed little over that time period (Compton, 1985). Classic tools of the field geologist still include the Brunton compass, hand lens, geologic hammer, and field books; but now also include new tools such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), and smartphones (Figs. 1–3).

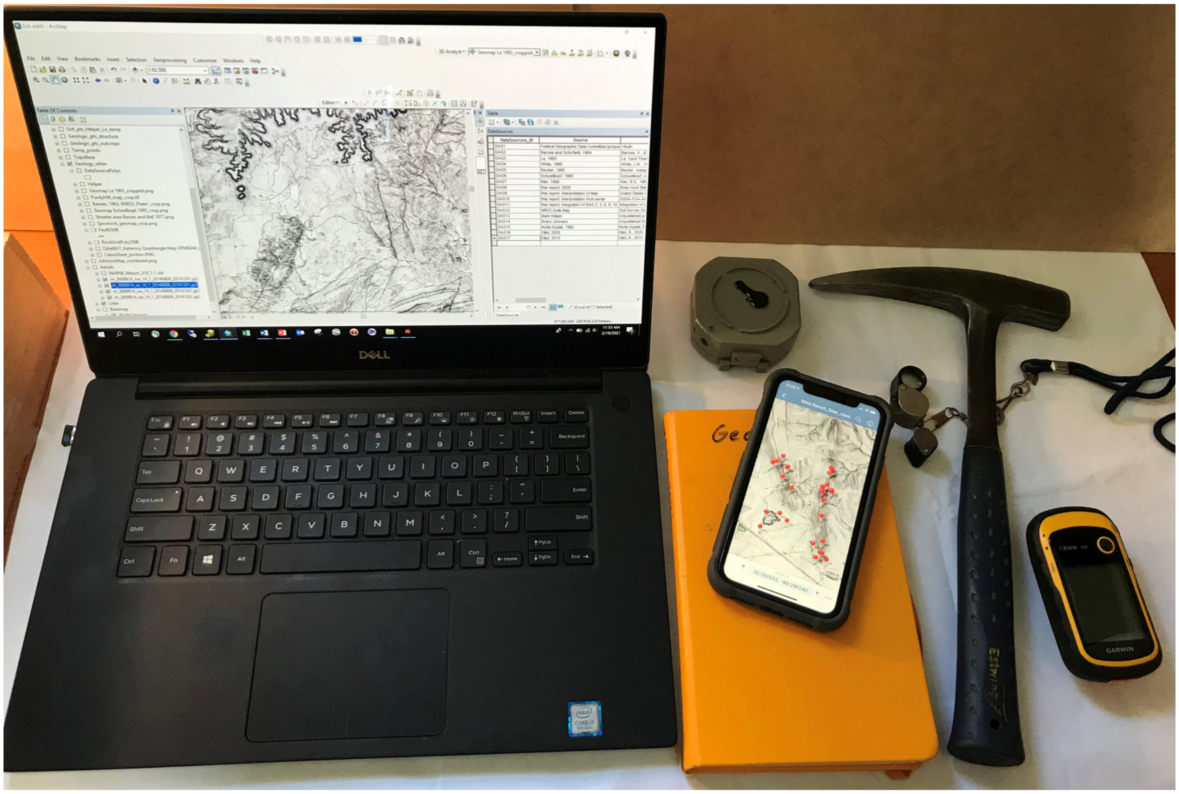


Figure 1. Photograph of mapping tools used in this study (from left to right): laptop with GIS, iPhone with mapping application, Brunton compass, field book, hand lens, hammer, and backup GPS.

Major changes in the approach to geologic mapping have occurred since the advent of GPS, GIS, readily available digital data, and other technologies (Soller, 1997; Pavlis, et al, 2010; Whitmeyer et al., 2010; Spencer, 2018). GIS and information technology has not replaced standard geologic methods and principles, but provide new techniques for to manage, transfer, analyze, and archive information that standard paper map production does not allow (Soller, 2004). Thus, GIS has become the standard interface for geospatial data and the production of geologic maps (USGS NCGMP, 2010). Development of the geologic map database used in this mapping project is described in GeMS (2020).

Modern base maps have dramatically improved precision and detail of the earth's landscape and topography. In particular, the use of orthophotographs, lidar, and lidar-derived maps such as hill shade and slope maps are powerful mapping tools for the field geologist (Figs. 2 and 3).

Hardware and software tools are constantly improving (Pavlis et al., 2010). Smart phones or tablets have become essential for field mapping and data collection, allowing the use of GPS, camera, and geological or data collection software applications (apps) in one small device (Figs. 1 and 3). While photographs are important and frequently supplement field notes, they cannot replace the field book or sketch, which aid in focused observation and interpretation (Maley, 1994; Genge, 2020).

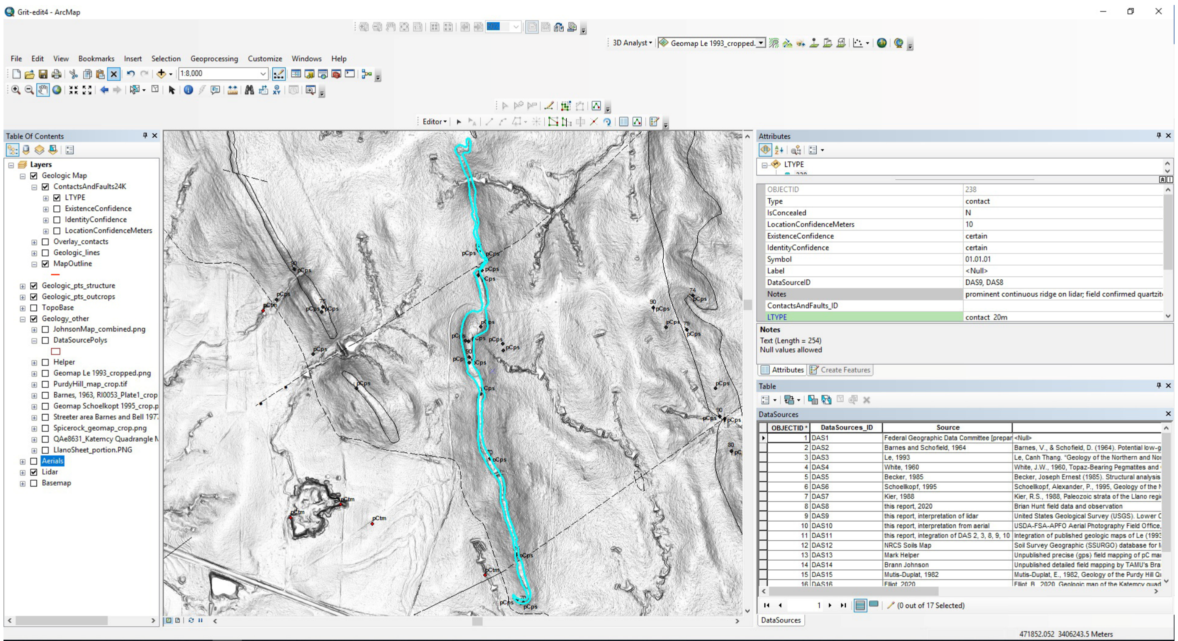


Figure 2. Screen shot of the GIS work that corresponds to Figure 3. The highlighted line is the contact line in GIS of the mapped quartzite. Note the data tables and associated attributes.

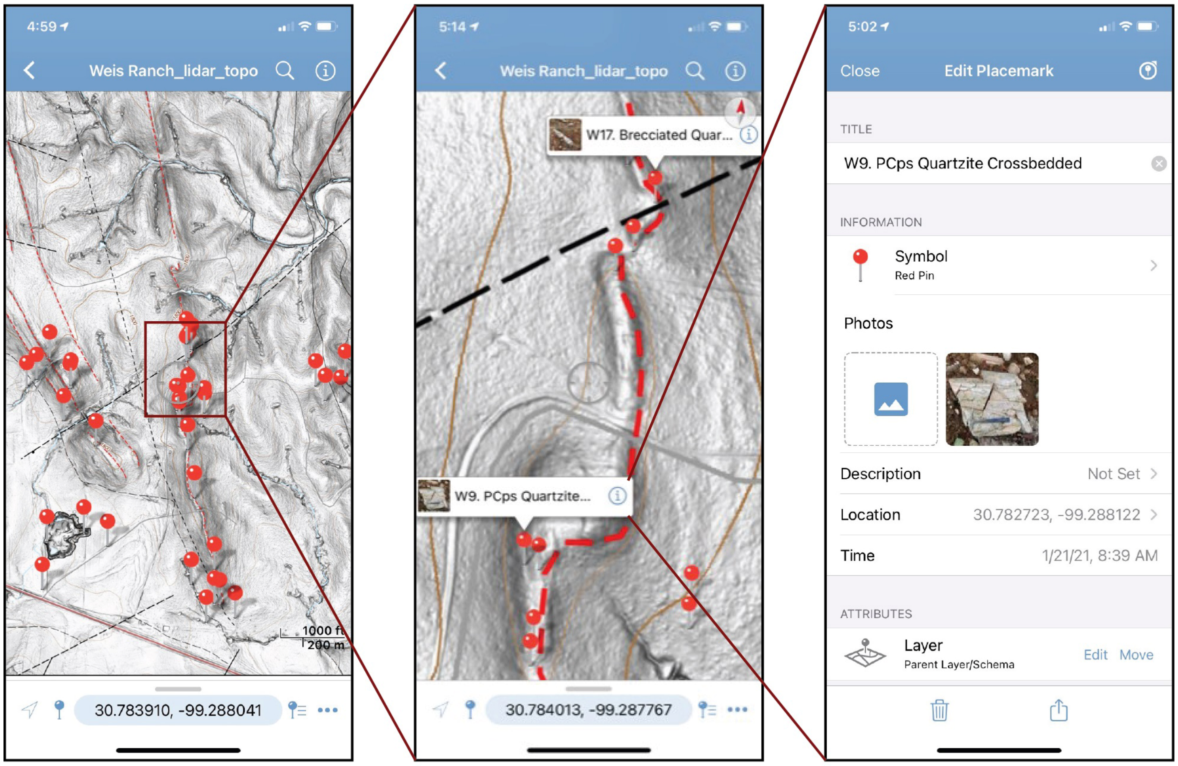
Approach to Geologic Mapping in Central Texas

The use of GIS has led to the development of different approaches and work flows to geologic mapping and has led to the refinement of long-established fieldwork paradigms (Pavlis et al., 2010). For example, the long-held field geology "rule" that (paper) field maps are finished in the field is no longer valid. The new digital approach to mapping allows creation of a partially completed geologic map even before going into the field. This is done by using existing published map data with the interpretation and integration of base-map data describe above. Field work then allows focus on verification, specific problem areas, and testing of geologic hypotheses (Pavlis et al., 2010). A general outline for the work flow of the example map includes:

(1) GeMS (2020) geodatabase structure.

- Base maps. Download and processes base maps such as topographic quadrangles, orthoimagery, and high-resolution digital elevation models. One of the most important data sets used in mapping is orthoimagery, hill shade, and slope maps derived from lidar (StratMap; https://tnris.org/stratmap/).
- Georegister existing maps. Compile all relevant geologic maps, theses, and other relevant data (Barnes and Schofield, 1964; Mutis-Duplat, 1982; Le, 1993; Elliot, 2017, 2020).
- Develop supporting information tables. Compose an initial Description of Map Units (DMU) and Data Source (DAS) tables for input into feature metadata in the GIS.

(2) Create preliminary geologic map. Create geologic lines, such as contacts and faults, using the combined base maps (lidar, orthoimagery) and published geologic maps. Each feature contains attributes and is symbolized accordingly (Fig. 2).



(A) (B) (C)

Figure 3. Smartphone screen shots of the mapping application used to collect field data: (A) View at ~1:20,000 showing hillshade with vertical exaggeration (10x), and topographic contours. Red dash lines are initial GIS mapping based on lidar and orthoimagery. The pins are subsequent point-data collected in the field. (B) View of a portion of the quadrangle (1:5,000) showing preliminary mapped trace of linear feature. The dashed black line was a fault, confirmed in the field. (C) View of the point data entry interface for a cross-bedded quartzite exposure. The site ID, unit, and any structures were recorded. A photograph and additional notes were added. The coordinates, data, and time are automatically recorded.

(3) Iterative field work, geologic mapping, and map data base development. Field work focuses on verifying geologic features, resolving problem areas, and testing hypotheses for the preliminary map. Field data are collected using smart phone or tablet apps with the preliminary geologic map. Avenza Maps is the primary software used in this mapping (https://www.avenzamaps.com; Fig. 3). Field data are integrated and the GIS-based map is iteratively revised.

(4) Finalize Map Data base and Map Layout

- Edit the map data base for compliance with the GeMS (2020) standards.
- Create map layout with standard graphics software according to the Bureau's geologic map standards for an Open-File Map.

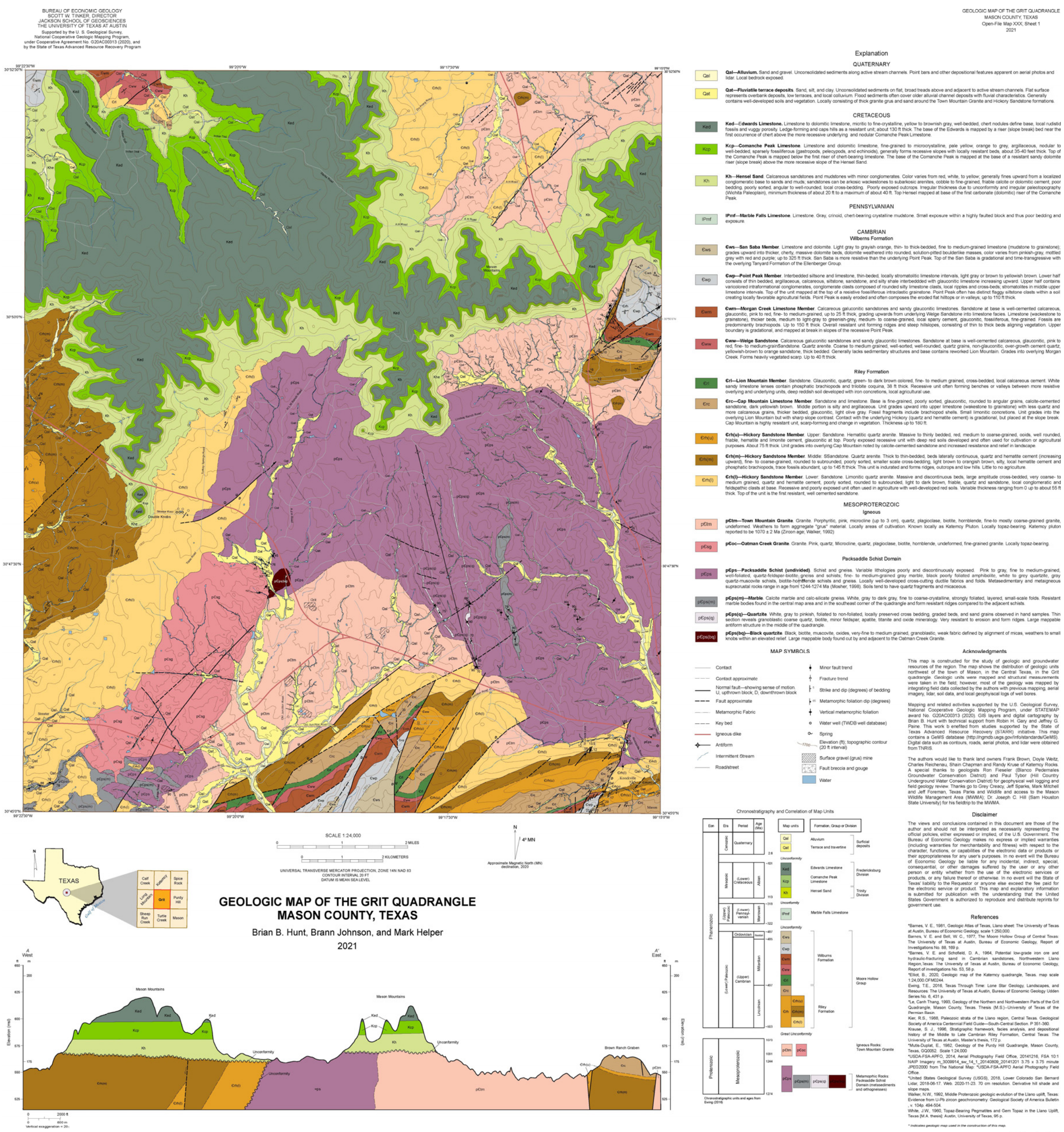


Figure 4. Draft Open-File Geologic Map of the Grit Quadrangle (Hunt et al., in review).

RESULTS

The final GIS map database follows the GeMS schema, and a final draft Open-File Map (OFM 252) was constructed using standard graphics software (Fig. 4).

SUMMARY AND CONCLUSIONS

The new technologies and methods described here enhance and supplement standard mapping methods, rather than replace them. The production of geologic maps now involves the creation of a geologic map database in the digital GIS environment following the schema outline by GeMS (2020). This is a major shift for geologic maps from a static to a dynamic and readily updateable product. In summary, field geology and digital map production are now integrated. The example applied to geologic mapping in the Grit Quadrangle is one approach to integrating the methods. The resulting geologic map and map database will serve as the foundation for future minerals, groundwater, and earth science research in Central Texas.

REFERENCES CITED

Barnes, V., and D. Schofield, 1964, Potential low-grade iron ore and hydraulic-fracturing sand in Cambrian sandstones, northwestern Llano region, Texas: Bureau of Economic Geology Report of Investigations 53, Austin, Texas, 58 p.

Bernknopf, R. L., D. S. Brookshire, D. R. Soller, M. J. McKee, J. F. Sutter, J. C. Matti, and R. H. Campbell, 1993, Societal value of geologic maps: U.S. Geological Survey Circular 1111, 53 p.

Compton, R. R., 1985, Geology in the field: J. Wiley and Sons. New York, 412 p.

Elliott, B. A., 2017, Geologic map of the Pontotoc Quadrangle, Texas: Bureau of Economic Geology Open-File Map 230, Austin, Texas, scale 1:24,000.

Elliot, B., 2020, Geologic map of the Katemcy Quadrangle, Texas: Bureau of Economic Geology Open-File Map 244, Austin, Texas, scale 1:24,000.

GeMS (U.S. Geological Survey National Cooperative Geologic Mapping Program), 2020, Geologic Map Schema (GeMS)—A standard format for the digital publication of geologic maps: U.S. Geological Survey Techniques and Methods, Book 11, Chapter B10, 74 p.

Genge, M. J., 2020, Geological field sketches and illustrations: A practical guide: Oxford University Press, U.K., 293 p.

Hunt, B. B., B. Johnson, and M. Helper, in review, Geologic map of the Grit Quadrangle, Mason County, Texas: Bureau of Economic Geology Open-File Map 252, Austin, Texas, scale 1:24,000, 2 sheets.

Le, C. T., 1993, Geology of the northern and northwestern parts of the Grit Quadrangle, Mason County, Texas: M.S. Thesis, University of Texas of the Permian Basin, Odessa, 73 p.

Maley, T. S., 1994, Field geology illustrated: Mineral Land Publications, Boise, Idaho. 316 p.

Mutis-Duplat, E., 1982, Geology of the Purdy Hill Quadrangle, Mason County, Texas: Bureau of Economic Geology Open-File Map 52, Austin, Texas, scale 1:24,000.

NCGMP (U.S. Geological Survey National Cooperative Geologic Mapping Program), 2010, NCGMP09—Draft standard format for digital publication of geologic maps, version 1.1, *in* D. R. Soller, ed., Digital mapping techniques '09—Workshop proceedings: U.S. Geological Survey Open-File Report 2010–1335, p. 93–146, 4 appendixes.

Pavlis, T. L., R. Langford, J. Hurtado, and L. Serpa, 2010, Computer-based data acquisition and visualization systems in field geology: Results from 12 years of experimentation and future potential: Geosphere, v. 6, p. 275–294.

Soller, D. R., ed., 1997, Digital mapping techniques '02—Workshop proceedings: U.S. Geological Survey Open-File Report 97–269, 120 p.

Soller, D. R., 2004, Introduction to geologic mapping, *in* McGraw-Hill Yearbook of Science & Technology 2004: McGraw Hill Company, New York, p. 128–130.

Spencer, E. W., 2018, Geologic maps: A practical guide to preparation and interpretation, 3rd ed.: Waveland Press Inc., Long Grove, Illinois, 221 p.

Thompson, R., 2021, New generation geologic mapping—A function of time, scale and purpose. [online zoom presentation]: Geologic Mapping Forum, February 11, 2021, <https://cse.umn.edu/mgs/events/geologic-mapping-forum-online-2020-2021>.

Whitmeyer, S. J., J. Nicoletti, and D. G. De Paor, 2010, The digital revolution in geologic mapping: Geological Society of America Today, v. 20, no. 4, p. 4–10.