Computers & Geosciences 44 (2012) 24–30

Contents lists available at SciVerse ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

GeoTools: An android phone application in geology

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ARTICLE INFO

Article history:
Received 10 November 2011
Received in revised form
23 February 2012
Accepted 25 February 2012
Available online 5 March 2012

Keywords:
Smartphone app
Digital field notebook
Field trip
Android

ABSTRACT

GeoTools is an Android application that can carry out several tasks essential in geological field studies. By employing the accelerometer in the Android phone, the application turns the handset into a pocket transit compass by which users can measure directions, strike and dip of a bedding plane, or trend and plunge of a fold. The application integrates functionalities of photo taking, videotaping, audio recording, and note writing with GPS coordinates to track the location at which each datum was taken. A time-stamped file name is shared by the various types of data taken at the same location. Data collected at different locations are named in a chronological sequence. At the end of each set of operations, GeoTools also automatically generates an XML file to summarize the characteristics of data being collected corresponding to a specific location. In this way, GeoTools allows geologists to use a multimedia approach to document their field observations with a clear data organization scheme in one handy gadget.

1. Introduction

There are tools that geologists always carry with them on geologic field trips for field data gathering; hammers to collect samples, field notebooks and pencils to sketch outcrops and to take notes of field observations, a GPS receiving unit and maps to track the various stops, and a Brunton compass to measure the orientations of various geologic objects. The list of the tools grows longer as one wishes to collect more types of information to better document the field study. However as the number of tools increases so do the types of data collected and this poses issues in itself. First, it is inconvenient for one to carry a large number of tools to the field. Second, the post-trip task to correlate data acquired from the various devices can be challenging and the difficulty increases with the varieties of data. Meanwhile, human errors may well be introduced during the process of transcribing data of non-digital format as handwriting in a field notebook can get smudged or unrecognizable; typos and unintentional mismatches among data can occur as well. Data storage and organization is another issue that calls for a bookkeeping system to help keep track of various raw data acquired for each geologic object and make them available for further analyses.

The latest development of smartphones offers some immediate help to the problems stated above given the large number of functions with which they are equipped. Smartphones, such as iPhone and Android phones, offer ample storage capacities commonly in the range of 8–32 gigabyte and advanced connectivity though Wi-Fi or 3G/4G networks. They can store hundreds, if not thousands, of multimedia files at a time. These data files can subsequently transferred to a remote locality for permanent storage via the Internet. They also come with a number of very desirable functions, such as keyboard/virtual keyboard, camera, recorder, digital compass, GPS receiver, and accelerometer. A single smartphone can thus take the place of an assortment of devices and provide the like functions in field information documentation for geologists (Sun et al., 2010).

Besides the advantages of storage capacity and connectivity, smartphones are also equipped with processors and memories that are comparable to personal computers. Various types of field data could be correlated with ease as long as they had been indexed spatially and temporally when they were recorded. The authors thus suggest taking further advantage of smartphones' great capability in computation and connectivity to construct a data management scheme that can organize field data on the basis of their spatial and temporal characters. Smartphones also afford options of immediate data manipulation and permanent data storage by either directly uploading data to a personal computer or by transmitting data to a remote site given that a 3G/4G network or Wi-Fi is available.

To this end, an Android phone application, GeoTools, has been created to assist geologists with the collection of field data, as well as data management.

2. Android App Development

Android is an Operating System for mobile devices, and it is developed and trademarked by Google (Android Developers, http://developer.android.com). Major phone service companies carry various kinds of Android Phones, made by different

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doi:10.1016/j.cageo.2012.02.027

manufacturers. To develop applications (apps) for Android Phones, Google provides Android Software Developer's Kit (Android SDK) that can be downloaded from its Android Developers website. The programming language used in Android App development is Java (Java, http://www.java.com). It is a common practice that software developers use Eclipse (Eclipse IDE, http://www.eclipse.org) as the integrated development environment (IDE), install the Android Development Tools (ADT) Plugin, and integrate the Android SDK to develop apps for Android Phones. There are currently two Android Developer Phones available (Android Developers, http://developer.android.com), ADP2 and Nexus One. We used the ADP2 in this project. One can download Android apps from Android Market (Android Market, http://market.android.com) or from third-party websites. Some service carriers also own their own market store for apps developed solely for the devices they sell. There are many websites that provide free tutorials for developing Android Apps. Many books are also available for Android App development (Ableson and Sen, 2011; Conder and Darcey, 2009; Hashimi, 2010; Meier, 2009).

3. Features of the GeoTools

GeoTools (Fig. 1) was designed and developed on the Android developer phone 2 (ADP2). Major hardware features (Android Developers, http://developer.android.com) include: Android 1.6 OS, 3.17 in. display, capacitive touch screen, 512MB FLASH memory, Wi-Fi 802.11b/g, 3 megapixel auto focus camera, microSD memory slot for a memory capacity up to 32 GB, USB 2.0, and GPS/assisted GPS. When used in geologic field trips, it can (1) take GPS coordinates, (2) measure strike and dip, (3) take photos, (4) take notes, (5) record voice memos, (6) record video clips, and (7) organize the acquired data mentioned above. The design of each utility and its significances are described in detail in the following sections.

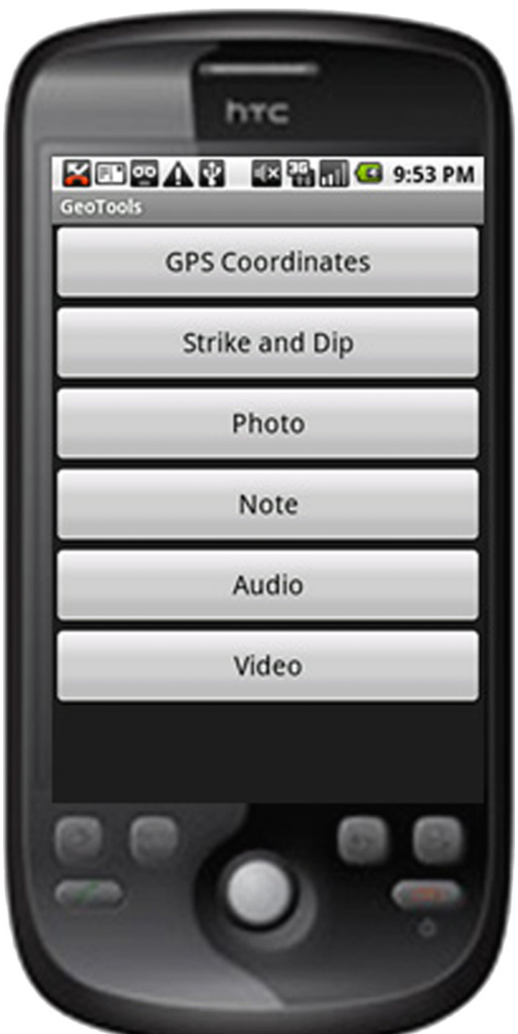

Fig. 1. GeoTools was developed on the Android developer phone 2(ADP2). The menu lists the six types of data that it can collect.

3.1. GPS coordinates recording

Field geology is a location based science. The first action a geologist takes in the field is to locate a geological object of interest and find its GPS coordinates. The GPS unit has become an essential tool for every field geologist. GeoTools allows the user to acquire and save a set of GPS readings consisting of longitude, latitude, and altitude (Fig. 2) as the first set of data collected at each geologic location. This location information is then automatically tagged to each photo, note, audio, and video taken at that location. One can choose to turn off the GPS receiver during transit to a new location or to restart the application. In this way the app eliminates the common concern that the battery power of the phone may soon be drained by the constant use of the GPS receiver.

3.2. Measurement of strike and dip

Another routine for field geologists is to measure the attitudes of geologic features such as bedding, folds, and faults that call for the measurement of either the direction of horizontal lines and/or the inclination of planes. The Android phone comes with an accelerometer that detects the magnitude and direction of changes in

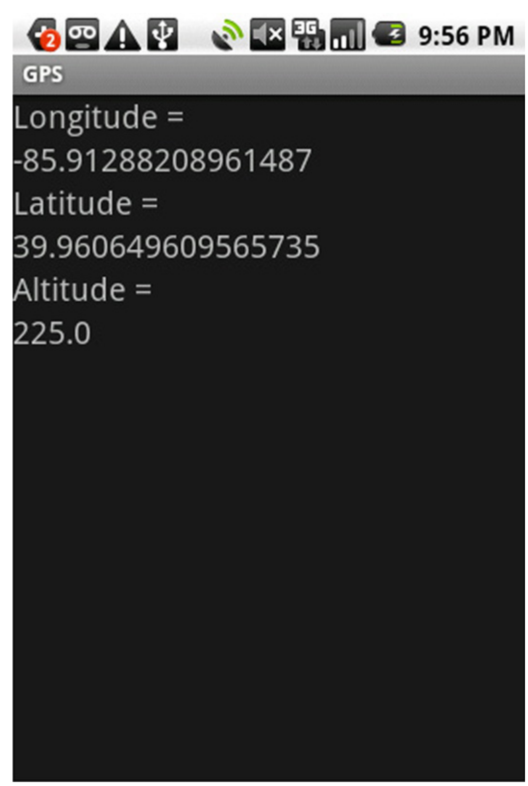

Fig. 2. The app records latitude and longitude coordinates as decimal degrees and altitude as meters. The latitude is preceded by a minus sign (−) if it is south of the equator (a positive number implies north), and the longitude is preceded by a minus sign if it is to the west of the prime meridian.

gravity or velocity, and thus enables a device to determine its orientation. With the device lying flat on a horizontal surface the screen is readable by the user in the portrait fashion with the control buttons next to the user, the *X* axis is defined from left to right, the *Y* axis goes lengthwise of the screen, and the *Z* axis goes upwards perpendicular to the screen (Fig. 3). The accelerometer values indicate the acceleration in units of 1 equals 1 g, which is 9.8 m/s^2, along the *X*, *Y*, and *Z* axes, which means a device in free fall would have an acceleration value of (0, 0, 0). Thus a stationary device will have an acceleration value of (0, 0, -1).

Combining the utilities of the compass and accelerometer embedded in the Android phone, GeoTools is adapted to measure strike and dip of any planar feature. Users can perform the measurement by placing the phone in a readable portrait fashion onto a surface as such that the lengthwise dimension conforms to the slope of the surface and the short ends of the phone represent the strike direction of the surface if it is adjusted to the level of X–Y plane as sensed by the accelerometer. The attainment of such an alignment is indicated when the "level" of the app reads zero (Fig. 4). In the mean time it also makes the inclination along the lengthwise dimension the dip angle of the surface.

3.3. Photo taking

Geologists used to sketch the outcrops to give a summary of key structural and geological features, to record field observations

Fig. 3. The respective orientation of *X*, *Y*, and *Z* axes when applying the phone's accelerometer.

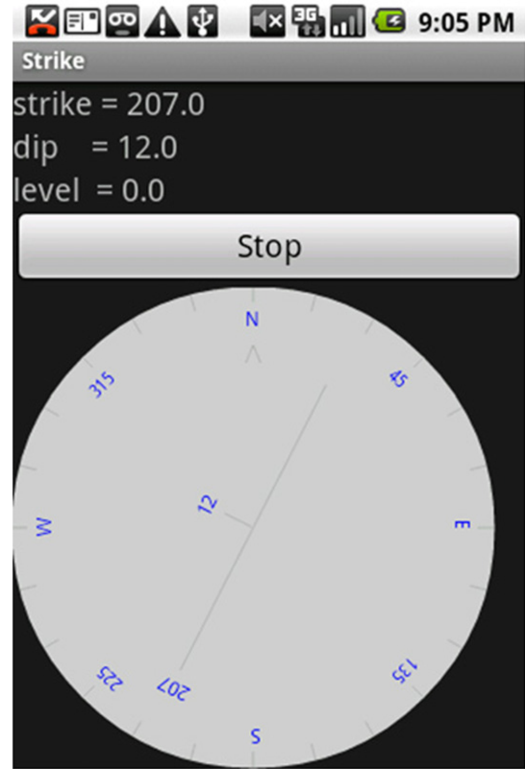

Fig. 4. The app tells the strike and dip of a plane when the phone rests on the plane and orients to a position in which the reading of "level" is zero. The readout of strike ranges from 0 to 360 degree, while that of the dip is from 0 to 90 degree.

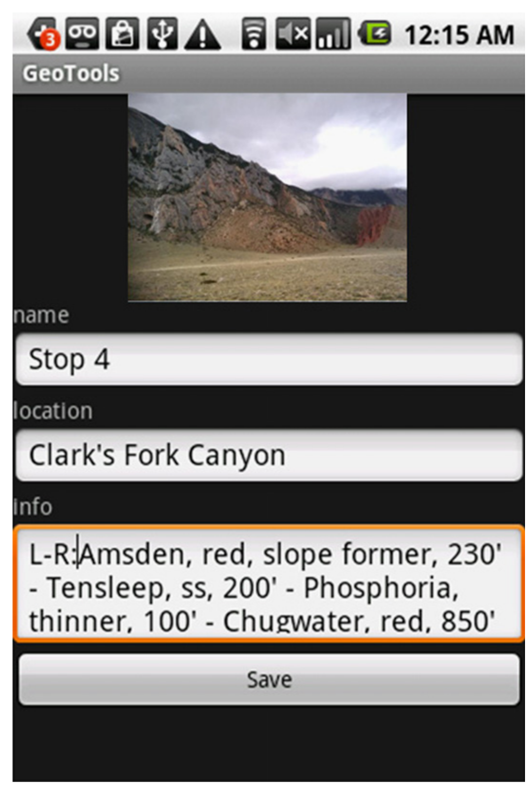

Fig. 5. When the "Note" mode in GeoTools is called upon for use, the photo of the object in interest will be prompted at the top of the screen; users can name the photo, give a brief description about the location, and explain the details of the object in the Info area.

and measurements, and to provide useful memory aids. While there is a benefit in using drawings, in that certain features can be accentuated in an image for emphasis, photographs take much less time and are used more and more frequently in place of hand drawings. GeoTools uses the Android phone's camera that has a resolution of 3.1 megapixels to takes photos and save them in a jpeg format. Users can examine the photo immediately and decide if a retake is necessary or photos in different scales serve the purpose better. Each photo is tagged with a GPS location and elevation.

3.4. *Note taking*

In contrast to the long-established paper and pencil method, users of GeoTools compose field notes by using the embed keyboard, a process similar to texting, which is common in most people's lives, especially among the younger generation. When the "Note" mode is called upon for use with the photo of the object of interest will be prompted at the top of the notepad to assist with the information editing (Fig. 5). The notes can be then electronically transferred to a personal computer or possibly immediately to a server for the purpose

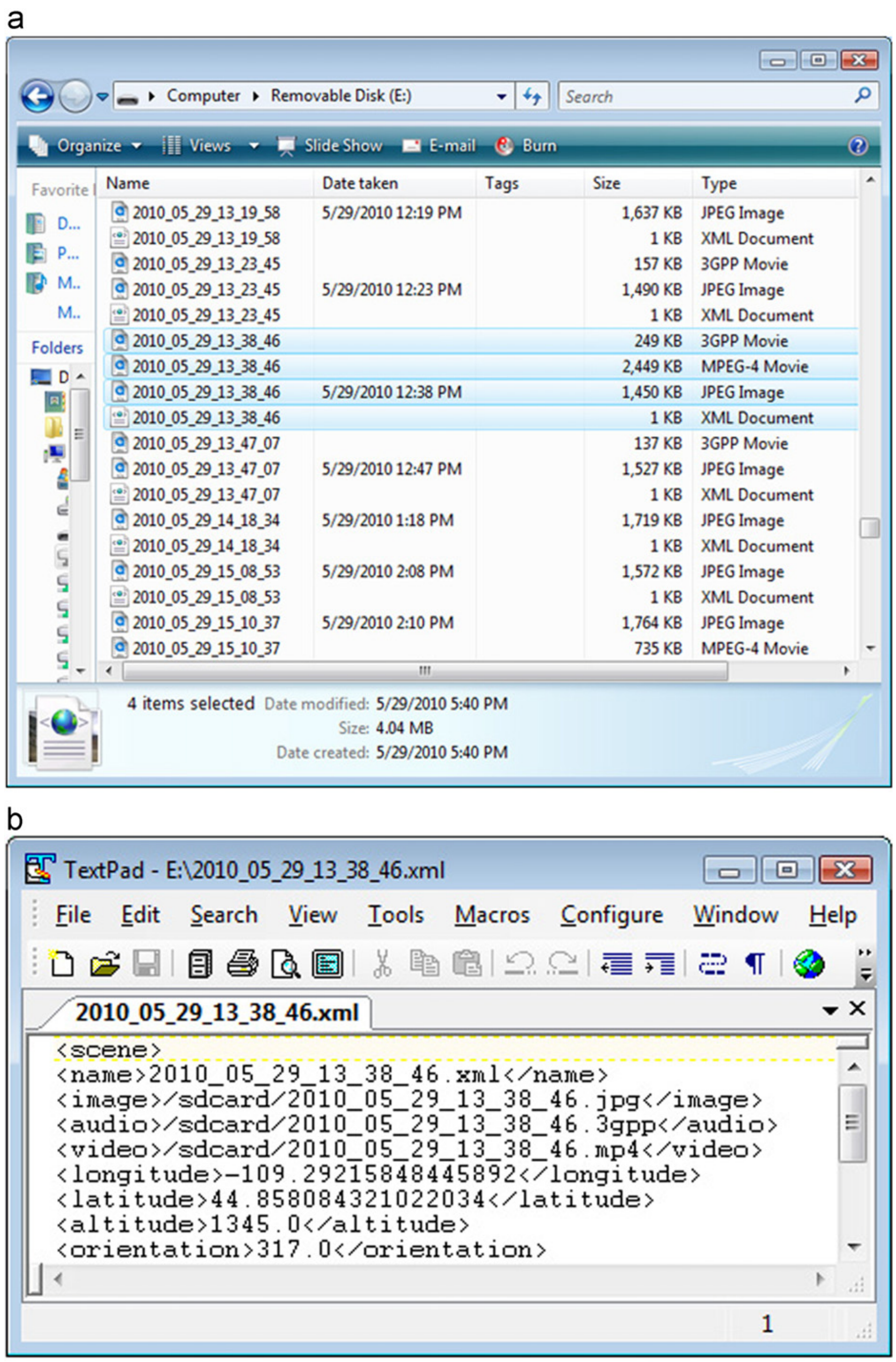

Fig. 6. Various data collected by using GeoTools. (a) Files highlighted show that at 13:38:46 5/29/2010, the user initiated a GPS recording and collected three types of data, an audio in the 3gpp format, a video in the mpeg-4 format, and a photo in the jpeg format, at the scene. An XML document was created by the app automatically at the end of the action for this stop. (b) The XML file keeps a record of each use of the app regarding the datum type, the location at which each datum was stored, the datum name, and the corresponding GPS coordinates.

of data storage or further editing. It is a great advantage of the system that exempts the user from the possibility of human errors being introduced as transcribing data from the traditional notebook.

3.5. Audio and video recording

The voice memo is a very useful yet overlooked feature that Android phone can offer to geologists. In the field, voice memos can replace note-taking, so one can quickly record observations as he/she goes. The field description in written format can be added on the basis of the audio recording after returning from the field. It is particularly effective when taking field notes is difficult such as during cold and/or windy days. The application takes audio recordings and saves them in the popular 3gpp format.

A video clip is an excellent way to document the overall geology of the outcrop especially when the outcrop is wide-spanned. It also offers information unparalleled to other means for fast on-going geologic processes; no words can compare with the power of video recording of a Kilauea lava flow or mud pots in the Yellowstone National Park. The application takes video recordings and saves them in the mpeg-4 format. It plays back the recordings immediately as well to allow the user to examine the quality and content of the audio/video recordings.

3.6. Data organization

By far, GeoTools offers functions in a single hand held device that can only be matched by combining various conventional tools commonly carried by the field geologist. Considering the fact that the capability of the Android phone is comparable to a compact computer, GeoTools has the potential to offer even more.

The Android phone uses a microSDHC card for data storage. The removable storage has a memory capacity expendable up to 32 GB that provides ample space for temporary data storage. To transfer data to permanent storage or retrieve data for further data manipulation, users can directly connect the microSDHC card to a personal computer via a miniSD slot, a USB adapter, or Bluetooth. They can also browse the stored data and transfer them from the phone to remote locations through the Internet if Wi-Fi or 3G data networks are available. Taking advantage of the excellent storage capacity and the great flexibility in connectivity the Android phone possesses, GeoTools can offer users data management in a timely and flexible manner.

When data are collected by different conventional tools during a field trip, the task to correlate the various types of data becomes as much of a challenge as the field work itself for geologists. GeoTools employs a unique data naming scheme that ties the data with both their location and their type. First it applies a time stamp, the moment at which the GPS reading was taken, to the first part of the file name of the collected data. Then different types of data related to the same location are to have this same time stamp but trailed with their own format. For example, as shown in Fig. 6(a), a photo file was named as year–day–hour–minute–second dot jpeg (2010_05_29_13_38_46.jpeg) and a video clip taken at the same stop was named as the same year–day–hour–minute–second but dot 3gpp for its own format (2010_05_29_13_38_46.3gpp). When the data files are sorted by name, they will be in a chronological sequence, which makes it easy for users to identify the various data related to the same geological object, which were presumably collected successively.

GeoTools is also programmed to automatically create an Extensible Markup Language (XML) (Extensible Markup Language, http://www.w3.org/XML) document (Fig. 6(b)) at the end of each deployment of the app. The XML file provides a textural summary regarding the datum variety, the location at which each datum was stored, the datum name, and the corresponding GPS coordinates at each scene. It keeps a record of the related data as such that the users will be able to trace each of them.

A major advantage to record the collected data in XML format is that it is directly machine readable and communicable. There are many application software systems that can process XML data. Geologists can integrate any of these systems that suit their specific needs. For example, since geographic coordinates are embedded in our XML files, our data can be easily converted to KML format and then displayed on Google Earth. We had previously developed an interactive data management system (Weng et al., 2010) that accepts geologic data in XML format and employs Google Earth as a visualization platform. According to the user's selection, the web system dynamically pulls the selected data from the database to create a KML file and then displays the collected information such as photos, videos, audios, and text description of selected locations on the Google Earth (Fig. 7) that virtually connects system users to the field.

4. Field Testing

To test GeoTools' strike-and-dip function, side by side comparisons between ADP 2 and a regular Brunton compass were carried out by measuring the attitudes of 10 acrylic boards, which ware

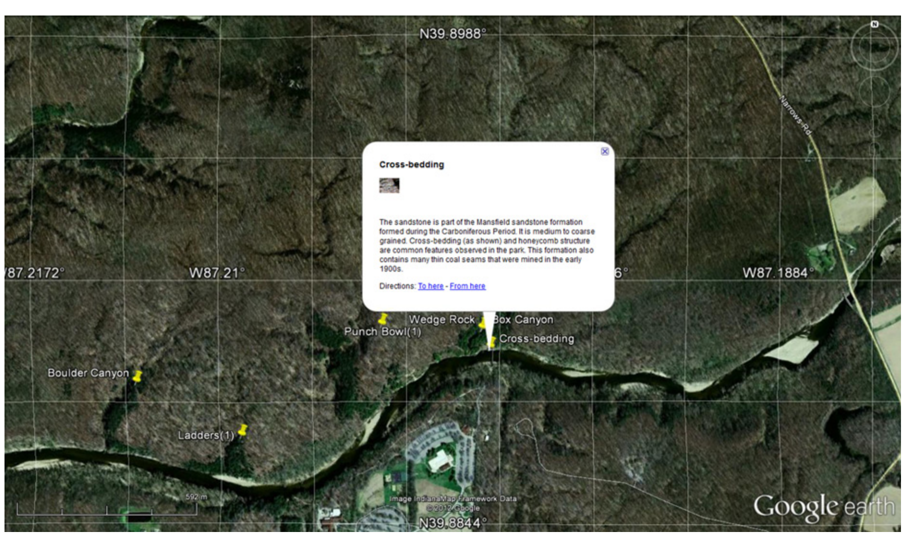

Fig. 7. Google Earth was employed to display location, image and description of outcrops at the Turkey Run State Park, Indiana.

arranged to represent 10 planar surfaces with varying orientations. Results are listed in the Table 1. As shown, GeoTools has the same dip readings as the Brunton compass does in eight out of the ten paired measurements and the differences of the other two measurements are one degree only. The paired measurements of strike also differ in a small range, from zero to four degrees. It is thus concluded that GeoTools works comparably as a Brunton compass does regarding the strike-and-dip function.

Field testing of the other functions of GeoTools was conducted during the excursion to Clarks Fork Canyon, part of the 2010 Ball State Summer Field Camp in the northern Rockies.

Clarks Fork Canyon is located to the northeast of Yellowstone National Park, where the Clarks Fork leaves the Beartooth and Absaroka Mountains and heads toward the Bighorn Basin (Fig. 8(a)). In a segment less than 10 miles along the Canyon Road to its western end, one can see the sequential rock formations that span from Precambrian granitic bodies to Quaternary glacial deposits (Heasler et al., 1996). Although the rock formations are not accessible at the roadside, which prohibits direct measurement of strata's attitudes, their characteristics are distinguishable remotely from the Canyon Road. The one-piece GeoTools thus came in handy to collect information in various

Table 1
Strike/dip of 10 planes measured by a conventional Brunton compass and GeoTools, respectively.

	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5	Plane 6	Plane 7	Plane 8	Plane 9	Plane 10
Brunton	018/54	027/20	038/48	046/37	081/24	084/30	186/30	222/72	258/17	323/24
GeoTools	018/53	031/20	039/49	048/37	080/24	083/30	188/30	222/72	261/17	322/24

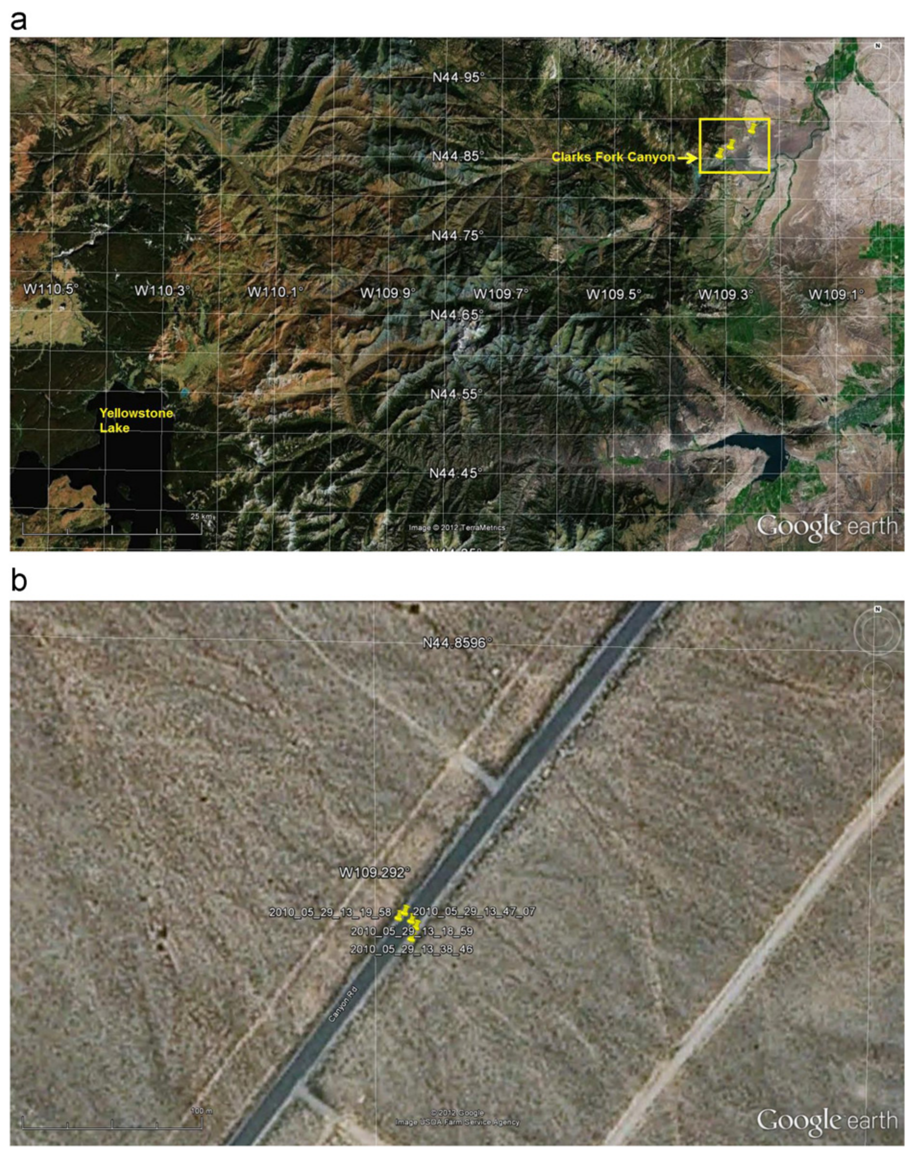

Fig. 8. (a) The yellow rectangle outlines the geographic location of Clarks Fork Canyon on the Google Earth. Also shown is the Yellowstone Lake at the lower left corner of the map, about 100 km from the study area. Nine stops that cluster into three yellow placer markers were made along the Canyon Road to gather information of various rock formations during the excursion. (b) Zooming in around the middle placer marker in the Fig. 8(a) reveals the detailed locations of five separate stops made along the Canyon Road. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

formats that suit for the situation sufficiently. It was used to capture images of the outcrops in distance and collect GPS coordinates at which photos were taken; functions of note and/or audio recordings were used to document the complex geological history, and videos were used to illustrate the regional geology in a grand scale from a sequential perspective. Part of the results is illustrated in Figs. 2, 5 and 6(a).

To verify if the ADP2's GPS receiver records acceptable measurements for geological purposes, we plotted the GPS coordinates collected during the excursion onto the Google Earth (Fig. 8(a) and (b). While collecting field data the author (Weng) moved and stayed on the course of the Canyon Road; as demonstrated in the zoomed-in plot, Fig. 8(b), the placer markers of stops cluster well within the bound of the road. This exercise confirms the accuracy of the Android's GPS function.

A temporary concern that the authors share is the resolution of the photo. While the quality of the picture with 3.1 megapixels seems alright at the phone's screen (Fig. 4), it looks slightly grainy on being brought up to a regular size display, such as on a computer monitor. This may pose a constraint on the usability of the photos taken by GeoTools implemented in models similar to ADP2. Upon the development of the most current smartphones, resolution of the embedded cameras has been improved up to 8 megapixels, which greatly eases the concern.

5. Conclusion

The advancement of smartphone technology has taken the smartphone well beyond the applications of a regular phone. It has great computing capability, storage capacity, connectivity, and most importantly it is GPS-enabled that suits one of the immediate needs of field geologists. Through the assistance of GeoTools, field geologists can save the trouble of carrying various tools into the field yet acquire the same data adequately. Moreover, the assortment of data can be related efficiently. The implementation of GeoTools demonstrates that, with the right software, smartphones can bring to geologists and other field scientists unparalleled benefits that range from multitasking and digitally recording data to effective data management that allows for simple archival and retrieval of the information collected.

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