UCR GeoPad Digital Field Mapping System

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This site is an effort to introduce a highly user-friendly, affordable, and adaptable digital field mapping and data collection system that has been developed and tested at UCR over the last two years. Based on the successes of implementing this technology in teaching and research so far (and the general lack of websites detailing digital field mapping in the geosciences) I was compelled to create this site.

The goal of this site is to share our methods, techniques, and experiences with the hope that it encourages further adoption of digital geologic field mapping in teaching, research, and industry. Many of the technology and techniques are perfectly adaptable to other disciplines like environmental sciences, botany, and archaeology.

Explore different topics using the menu at left. I'll do my best to keep the pages updated with the latest developments. A companion manuscript is in preparation describing the system, its advantages, and potential implementation. Welcome to the site!

A Field Geologist's Perspective

I come from a mapboard and Brunton upbringing, learning to map in many tried-and-true locales in southern California. Taking a measurement or locating myself on a map was never much of a concern, but I did find frustration in the degree of uncertainty inherent in locating from 40 foot contours and that I could not instantly switch between a topo map and an aerial photograph. Carrying out PhD fieldwork in New Zealand's temperate rainforest circa 2009 brought new challenges. With line-of-sight visibility through the bush often limited to about 10 meters, I quickly came to value a Garmin eTrex Legend GPS that I had preloaded with vector topo maps that enabled +/-5m positioning and effective navigation. I learned to put a degree of trust in this technological wonder, but a trusty Silva (my Brunton needle was not weighted for the Southern Hemisphere!) and field notebook still did most of the work. Once back from the field I could compile my GPS locations, notes, and measurements into a spreadsheet and import my data into ArcGIS (not particularly novel for the time). I followed developments to introduce field tablets into geologic mapping with great interest, but for the longest times they seemed to be burdened with greater disadvantages than advantages. They were pricey, heavy, fragile, had limited battery life, poorly visible and low resolution screens, glitchy software with steep learning curves, and they still relied on external GPS and compass requiring considerable manual data entry. With time these barriers were gradually being reduced but not altogether eliminated. The last twenty years of literature contains a patchy record of attempts, updates, and calls to arms to utilize digital mapping both in teaching and in research.

In 2015 I was awarded a UCR grant to explore the current state of field-capable mapping technology and develop a system that could be utilized in our new capstone Summer Field Geology course, and ideally other courses offered by the Department of Earth Sciences. This made price and ease-of-use especially important considerations. Over the last two years I've field tested about a dozen different hardware and software combinations over iOS/Android/Windows platforms. Based on current technology I can confidently say that a ruggedized iPad Mini/FieldMove-based system is the best option I have found. It is the only device that I am aware of that has accurate internal sensors that can both take measurements and locate positions. The advantages far outweigh the downsides and I have used it successfully in my own fieldwork in California, Mexico, and New Zealand over the last year and a half. The technology was successfully implemented in our summer 2016 undergraduate field geology course, and I am finding other courses that could use the tablet system on field trips. It is full steam ahead for us!

Based on the successes of implementing this technology in teaching and research, and the general lack of websites detailing digital field mapping in the geosciences, I was compelled to create this site with the goal of sharing our methods, techniques, and experiences with the hope that it encourages further adoption of digital geologic field mapping in teaching, research, and industry.

I am convinced we are finally here at the cusp of a digital renaissance that will enable a new generation of accurate, data-rich geologic mapping that is more easily shared and used than ever before. I expect some pushback to this technology, but hope that generally people can approach it with an open and willing mind. Yes there are downsides and disadvantages. Yes the technology can and will be improved. How stable and long-lived can a particular system be? Can we get ten years of life out of it? There are also legitimate concerns about increasing the ease of data accessibility in teaching- are we making it easier for students to cheat? In no way do I suggest digital field mapping techniques should completely replace traditional techniques in undergraduate curriculum. I do muse over whether we are now within a long transitional era, at the end of which paper-based field mapping will go the way of the abacus, slide rule, and typewriter, obsolete or specialist technology deserving a brief mention for historical value. Make no mistake, the world is going digital! The tools are now in place to take field geology there.

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Website Notes
- If you are deeply invested in Android or Windows-based systems, fret not, much of the functionality of this system and the steps walked through can be adapted.
- This website assumes a moderate level of technical capability, such as familiarity with GIS programs, iPad, and computer-based functions.
- There is likely a U.S. bias to some of the steps and data discussed. Apologies. Links or suggestions relevant to other portions of the world are invited.

Acknowledgements

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For additions, corrections, questions, or just to let me know that you found the content helpful please contact me at the email address below. If you would like to contribute content I would gladly consider it and acknowledge you appropriately.

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Update History
2 February 2017: All key content in place. Site shared widely.
3 November 2016: Site goes live!

The UCR GeoPad Digital Field Mapping System

We adapt the term "GeoPad" used by Science Education Research Center (SERC) to describe our iPad tablet-based field mapping system capable of integrated GPS/GIS/measurement/photo/data collection in a rugged field-ready format that can be held in one hand. This system is appropriate for field geology applications across teaching, research, and industry. Much of the technology and methods are also appropriate for other field-based disciplines such as environmental sciences and archaeology.

Trials and Tribulations

About a dozen tablet devices and several software suites were trialed (listed below) before we invested in a full class set of twenty tablets for student use. The trial process consisted of (1) self-trialing several different systems in the course of research fieldwork, and (2) selecting three undergraduates to trial the two most promising systems (iPad Mini 2, Microsoft Surface Pro 4) in the course of senior thesis projects.

Usability, functionality, robustness, and price were all key considerations. Each device and software combination has advantages and disadvantages that are beyond the scope of discussion here. Going into the project it was my hope was that a Windows-based product would give the greatest flexibility in and out of the field, but no such device currently exists that has reliable internal sensors capable of accurate structural measurements. In the Resources section you will find references to several software suites (both homegrown and third party) being utilized in field studies. If field collection of point-centric metadata is your primary concern, one of these other software suites may be better suited. For importing basemaps, point/line/polygon mapping of geologic features, measurements, annotated photos, and in-field stereonet visualization, I have found FieldMove to be the most powerful and intuitive software available. In the course of testing, an iPad Mini 2 in a ruggedized Lifeproof case running FieldMove emerged as the best compromise of available technology.

List of Devices Trialed
Getac Z710 (Android)
Samsung Galaxy Tab Active (Android)
Soten Technology T70 (Android)
Soten Technology T80 (Android)
Dell Venue 11 Pro (Windows)
Hewlett-Packard Stream 7 (Windows)
Panasonic Toughpad FZ-M1
Microsoft Surface Pro 4 (Windows)
iPad Air 2 (iOS)
iPad Pro (iOS)
iPad Mini 4 (iOS)
iPad Mini 2 (iOS)

(Partial) List of Software Trialed
ArcGIS 10 (Windows)
ArcPad (Windows)
iGIS (iOS)
Collector for ArcGIS (iOS / Windows / Android)
FieldMove Clino (iOS / Windows / Android)
FieldMove (**iOS** / Windows / Android)

Tipping the Scales

I will generalize that for the last 10+ years digital geologic field mapping has largely been treated as an expensive novelty with considerable promise that had difficulty delivering. With fast-moving technologies (tablets, GPS, UAVs, etc.) and the advent of new softwares, the last couple years have seen a dramatic shift that I'd argue have tipped the scales towards a digital field workflow.

Some of the key advantages and disadvantages of our GeoPad system are highlighted below. These can also be generalized as the current advantages and disadvantages of digital field mapping. I emphasize that both students and I agree that the advantages to this system outweigh the advantages of traditional paper-based mapping in most circumstances, both in research and teaching applications.

Key Advantages of UCR GeoPad System
+ **Shallow learning curve.** Intuitive and user-friendly hardware and software.
+ **Cost effective.** Starting at $350 per unit ($1100 each if greater memory, more apps, and high precision GPS are desired).
+ **All-in-one design.** One handheld device is capable of instant geolocation, mapping, measurements, notes, photos, annotations, stereonets, etc. One software program (FieldMove) is capable of all essential functions. All data and linework is easily editable and exportable.
+ **Efficient.** Place a georeferenced measurement or photo on the map in less than five seconds. Allows for greater data collection over traditional means. More ground can be covered more thoroughly in less time.
+ **Better geological understanding.** The ability to instantly switch between multiple basemap layers, adjust scale, or view structural data on a stereonet encourages better visualization of geological data in the field.
+ **Accurate.** Better than 10 m positional accuracy is readily obtainable with the iPad's built-in GPS (appropriate for many teaching and research-based applications). With an external Bluetooth-enabled GPS, positional accuracies of 1 m, or even 10 cm, are obtainable. This technology is improving rapidly and becoming more cost-effective. The high resolution and high sensitivity capacitive screen allows for accurate linework.
+ **Field ready.** Low profile design, lightweight, waterproof, dirtproof, dropproof, mostly student-proof…

+ **All-day battery life.** Apple claims the iPad Mini 2's 6471 mAh battery yields a 10 hour battery life but this of course depends on how you use it (and the operating temperature). In Airplane Mode with programs and GPS running in the background I have observed remarkably little battery drain. Essentially the battery goes to power the bright 7.9 inch display so your battery performance will depend on how long you are actively mapping or viewing compared to walking or driving between field sites. With intensive use I (and many students) have not managed to run a battery empty in a long day of fieldwork. In two years of frequent use of the same iPad I have not noticed any significant degradation of battery performance.

+ **Easy export.** Field data readily exportable to CSV / Move / GIS / Google Earth formats. Exported data can quickly be viewed, manipulated and compiled in desktop GIS programs. This increases the ability to rapidly map adjoining tiles and crowdsource data into a single database.

+ **Teaching ready.** Students enjoy using the intuitive software. Greater efficiency means better use of precious field time. "Live" measurement and stereonet functions help students understand these spatial concepts. Ability to annotate photos helps highlight how to make effective field sketches. The many compatible apps provide both a tool kit (scanner, photo library, word processor, reference, etc.) and field library (add PDFs of relevant textbooks, journal articles, and maps). Exported projects are easier to rank and grade than paper-based maps.

Key Disadvantages

- **Screen glare.** This remains a key hindrance. Hide the screen in your shadow or use a jacket as a sunshade when in bright sun.

- **Overheating.** Continuous use in >90 F temperatures (or leaving out in the sun on hot rocks) causes iPad to overheat, rendering it useless until it cools to operating temperatures. Good practices (keeping the iPad in its case when not in use) allow problem-free use in >100 F temperatures. Student learned to avoid this problem altogether with time...

- **Software glitches.** FieldMove is not immune to program glitches. Sometimes the GPS turns itself off. Sometimes created units are not selectable. Both students and I have encountered several instances of the program crashing (automatically closing to return you to the iPad home screen) when editing map features or navigating. This seems particularly common for projects with a lot of data or layer files. While annoying, the upshot is I have yet to see or hear of an instance where one of these crashes has lost data. You simply re-launch FieldMove and start where you left off.

- **Software limitations.** The structure of iOS greatly inhibits the ability to share data between programs, which limits functionality. Apple's software policy does not support retroactive updates. Essentially once you update iOS you are committed to that software version or a newer one. Every iOS update can create glitches or total loss of functionality in apps, including BadElf and FieldMove. For these reasons any update to FieldMove or Apple iOS software must be treated with caution (trial a new version at length on one device before committing to updating the rest). Will FieldMove continue to be updated to maintain compatibility with iOS versions?

- **Hardware limitations.** The move away from technology allowing user-upgradable components and towards sealed devices purposely replaced by newer offerings every 1-2 years makes the hope of a 10 year investment a lot less secure. If the battery dies or the screen loses

sensitivity it is unlikely either can readily be replaced five years from now. Are you hosed once the form-fitting waterproof cases are no longer manufactured and you run out of your stock of backups? A USB drive on an iPad would have been handy too. On the plus side Bluetooth and WIFI technology seem like they will change little and will continue to be supported.

- **Importing.** To make the best use of valuable field time you will have to invest some time in preparing all map layers that will be used to aid mapping (aerial photos, contours, hillshades, existing geologic maps, etc.) and importing them to the device. This may include selecting the correct area to export/import, converting between file formats, and manually georeferencing a older maps. Carrying this out admittedly can require more preparation time than just printing off a bunch of maps (but I would argue is time well spent if it leads to greater efficiency and understanding in the field.

- **Exporting.** To get full use out of the field data collected on a GeoPad it is necessary to "push" the data to a more fully featured laptop or desktop computer (e.g. Mac, PC) capable of running more intensive programs such as ArcGIS, Move, Illustrator, etc. As new device offerings continue to gain power and portability, it is conceivable that a single device could emerge capable of functioning as both the field and office device. The Microsoft Surface Pro 4 tablet/laptop hybrid (Intel i7 processor, 16GB memory, 1TB storage) is perhaps the best current effort towards this goal.

UCR GeoPad System Components
Click the arrows to expand the component's description. We issue one kit per student. Cost per kit starts at $350 each.

The Kit
iPad Mini 2 Cellular 16-64GB $250-450
- We chose the iPad Mini platform (over generally more versatile Windows and Android based systems, including field-ready rugged tablets) because no other device tested had as reliable internal sensors (GPS, clinometer, compass, camera). Screen quality (sensitivity/brightness/resolution), size, battery life, ability to be ruggedized, and cost were also critical considerations that generally ruled in the iPad Mini's favor.
- Avoid the iPad Mini 4 for the moment! We use the *iPad Mini 2* which is still sold by Apple and is also available via online retailers. The iPad Mini 4 (newest version) has several technical improvements over the Mini 2 (8 vs. 5 MP camera, fingerprint sensor, anti-reflective screen, 1.3x faster CPU, 1.6x faster graphics) but a fatal flaw in that Apple designed the Mini 4 to be 3mm longer, which makes it incompatible with all completely enclosed cases on the market. I have not found a marked speed or stability advantage of the Mini 4 over the Mini 2. The Mini 2 starts at $150 cheaper and accessories are available online at closeout prices. A further caution that the screenless Lifeproof NUUD iPad Mini 4 case has frivolous metal components that deflect the internal compass up to 40 degrees and render internal measurements unusable!
- I strongly recommend the **"Cellular" version** (specific carrier does not matter) as the "WIFI-only" versions do not have a GPS chip! The internal GPS on the cellular version can readily be used without phone contracts to obtain +/-10m positional accuracy. This is

an A-GPS chip which relies partly on cell towers to locate you; in wooded or very remote areas it can take many minutes to get an initial satellite fix.

- I suggest obtaining the largest internal memory possible (32GB for the iPad Mini 2) to allow plenty of large map layer files to be loaded and ensure room for apps and photos.

Lifeproof iPad Mini 2 Case $30-60

- These dustproof, waterproof, somewhat drop-proof cases allow full functionality of the touchscreen and all sensors. The all-plastic design ensures that the internal compass provides accurate measurements. The slim profile makes for easy handling. The iPad is charged via a flip port at the bottom. Once properly installed, there is no need to ever remove the case which keeps the iPad in pristine condition. If the case is dusty the easiest way to clean it is to run the whole case under a faucet. A neck strap (included) is a nice option many students preferred.
- These cases (originally retailing at $100) can currently be found an excellent prices through online retailers. The cases built for iPad Mini 1 or Mini 2 are preferable as the iPad Mini 3 cases feature a weak spot over the home button to allow fingerprints to be scanned (I have already seen a screen shattered from rock chips hitting this improbable bull's eye). Buy extra if you can as they will likely become hard to find as Apple moves on to other products. They are "lifeproof" maybe, but not necessarily student-proof. The case's screen will become scratched but protect the tablet inside. Cases built for iPad Mini 4 are incompatible!

External Battery $25

- For the price an external battery pack is well worth the investment to be sure your tablet does not run out of battery at some critical moment while in the field. There are many robust and reliable options available on the market (we trialed several). Assuming you have access to electricity in the evenings, a good option is the RAVPower 13400mAh 3.5A portable charger bank ($25), which has a slim design and is capable of fully charging an iPad Mini once before needing to recharge.

Neoprene Case $10

- I tried about a half dozen exterior cases and found the "CaseLogic iPad mini 7" tablet" case to be the best. No sleeve-style case that I have found is designed to house an iPad Mini in a Lifeproof case (which adds thickness in all dimensions) but this neoprene case will stretch to barely allow it. The handy zippered front pocket is ideal for storing GPS, stylus and other key accessories. The size and texture makes it very convenient to hold in a hand while walking across the field area. This particular case has stood up well to field abuse.
- This system actually has three layers of protection! The Lifeproof case (which should always be used), the neoprene case (which should always protect the iPad except when it is directly being used), and a large, sturdy plastic zip-lock bag (sized to contain the entire kit and protect from dust and rocks in backpacks).

Stylus $15

- Although a stubby finger works just fine for most applications, a stylus allows for near-pencil precision of linework and thus should be considered an important component of the kit. We like the Musemee Notier V2, which has a smart screw-on design that

protects the delicate tip when not in use (and comes with a spare tip). The tip consists of a clear plastic conductive disc which precisely averages the screen's capacitive response to the pencil-thick center.
- These tips do break from misuse and abuse so it is wise to emphasize proper use to students and purchase extra tips ahead of time.

Software $30-80
- FieldMove by Midland Valley ($30) is the critical "app" that makes the system work. A wide range of apps (both free and paid) are worth investing in to greatly expand the functionality of the GeoPads (word processing, pdf viewing, cloud sharing, wifi printing, geology reference, etc.). A full list of suggested apps and their function is detailed in the software section.
- Bonus! If all the iPad are linked to the same Apple account (detailed in the setup section), the software is a one-time expense (rather than per kit).

Bad Elf GPS (optional) $150-600
- If you purchased the cellular iPad and 10m GPS positional accuracy is good enough (true of most undergraduate-level mapping projects as we found out), then you do not need to purchase this item. For greater accuracy Bad Elfs (elves?) are user-friendly stand-alone GPSs that can wirelessly connect to an iPad via bluetooth and override the iPad's internally derived location. Essentially this can enable an iPad to give positionally accurate locations down to 1m accuracy without compromising the integrity of the iPad case. The Bad Elf has all-day battery life with its rechargeable internal battery.
- The Bad Elf Pro+ ($300 retail) is capable of 2.5m positional accuracy. The Bad Elf GNSS Surveyor ($600) is capable of out-of-the box 1.0m positional accuracy, and claims capability of 10-50cm accuracy with data post-processing ("coming soon" they say; watch out Trimble if they figure it out). For research-grade field mapping I have found the GNSS version to be a worthwhile investment.
- Bonus! A single Bad Elf GPS can connect to five bluetooth devices at a time in an 30ft radius, meaning if you have students working in groups they may only need one device per group.

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 $350-1100 per kit

Group Gear

Power strips
- Good quality power strips with surge protection capable of charging 6 outlet and 6 USB devices at the same time go for about $27. Buy as many as needed.

Storage container
- I use Rubbermaid ActionPackers (rugged plastic bins) to store and transport the tablets. They can also be locked with luggage locks for peace of mind.

Laptop computer (optional)
- While an instructor's laptop is perfectly suitable to interface with the GeoPads (setup/import/export), it may be preferable to have a dedicated laptop for this job.

Anything with a USB port and Apple's iTUnes software will do. I use a Microsoft Surface laptop/tablet hybrid that also has ArcGIS loaded.

Solar generator system (optional)
- If your field camp does not have electricity, a solar generator kit may be an option. The Goal Zero Yeti 1250 kit (~$2000) includes solar panels and generator and has energy storage for about 45 tablet charges. We have successfully charged over 15 tablets and UAV batteries overnight using only 20% of the Yeti's storage capacity.

Protecting Your Investment:

I *hope* to get 10 years of life out of our digital mapping system. While the greatest unknowns are probably future Apple iOS updates, third-party software compatibilities and the longevity of the iPad Mini 2's internal components (e.g. battery, sensors), it pays to plan ahead by purchasing extra components that will be hard to find as the technology changes.
Specifically:
- Spare stylus tips   (students will murder these if not properly instructed)
- Spare Lifeproof cases   (a lot cheaper than iPads!, will be very hard to find once the technology has moved on)
- Extra cables   (Apple charging cables, etc.)

Looking Ahead:

It's anyone's guess but here are some (wish-laden) anticipated improvements to this system that may be available soon if current trends continue.
- FieldMove
    - less buggy as software continues to develop
    - better integration with other software
    - better exporting options
    - Bluetooth sharing between GeoPads in the field?
- Bluetooth GPS
    - capable of 10 cm resolution
    - better integrated software
- Wireless battery charging?

Full Software List

Software can be download through Apple's App Store using the instructor's GeoPad. See workflow section to set up software on multiple devices. Many but not all apps are available on Android systems. Email me if I'm not up with the latest and greatest app offerings!

Mouse over the app name for a brief description.

FieldMove   Midland Valley $29.99
This is the essential software component of our GeoPad. Integrated GPS, multiple basemap support, structural measurements, stereonets, drawing and editing functions, annotated photos, and notes - it does it all!

Gaia GPS	Gaia GPS	$19.99

Probably the best featured mapping app available. A key strength lies in the ability to download data from many sources (topo, aerial, terrain, etc.) for offline use.

Theodolite HD	Hunter Research and Technology, LLC	$5.99

A simple app that takes photos with full positional data (azimuth, inclination, lat/long/elevation, roll) as an overlay. Useful for bearings, cosmogenic radionuclide sampling, and oriented samples.

Bad Elf GPS	Bad Elf, LLC	$0

View the status of a connected Bad Elf GPS, transfer trip data, and install GPS firmware updates.

Tiny PDF	Appxy	$0

Use to annotate, read, and manage PDF files. Effective way to give students journal articles or PDF maps.

Tiny Scanner+	Appxy	$4.99

Use the iPad's camera to scan documents into high quality PDF files.

Avenza PDF Maps	Avenza Systems Inc.	$0

Well-featured GeoPDF and GeoTIFF reader.

ArcGIS	ESRI	$0

Worth downloading if only to keep an eye on where they go with this app. May be useful for viewing ArcGIS data in the field.

Collector for ArcGIS	ESRI	$0

Allows for collection of GIS data in the field. FieldMove is superior for geological fieldwork, but this app's integration with the Bad Elf GNSS Surveyor means it's a good option if 1m accuracy locations are critical. Syncs well with other ArcGIS products.

KMZ Loader	Casey Evanoff	$0

Simple app that can load KMZ files (the Google Earth iPad app strangely can only open KML files!).

MBTiles GPS	Alan Pew	$0

Loads MBTiles files (useful as a troubleshooting option for FieldMove imports).

iGIS	Geometry	$0

A more functional mobile GIS app than mobile ArcGIS. A good option if generating metadata in the field is important.

Drive	Google	$0

Offers cloud-based storage. Our students' email accounts are linked to Gmail making Drive an excellent way for students to collaborate on data or turn in projects.

Docs	Google	$0

Excellent word processor app offering cloud-based storage and sharing.

Sheets	Google	$0

Excellent spreadsheet app offering cloud-based storage and sharing.

Slides	Google	$0

Excellent presentation app offering cloud-based storage and sharing.

Google Maps	Google	$0

Useful for its ability to cache high resolution satellite imagery.

Google Earth	Google	$0

Unfortunately nowhere near as fully featured as its desktop version (e.g. no editing capabilities) but probably worth the download to view landscapes in 3D.

Snapseed	Google	$0

Possibly the best photo editing app for the iPad.

Ruler Free	Dmitriy Pushkarev	$0

Turns your screen into a handy ruler or scale bar.

VSCO	Visual Supply Company	$0

One of the better apps for manual camera settings.

Oxford Dictionary of Geology and Earth Sciences	Mobile Systems	$9.99

Useful reference for students to have on hand.

Geotimescale Enhanced HD	Tasa Graphic Arts, Inc.	$0.99

Simple geologic time scale app. A PDF of the GSA timescale would work just as well.

Units Plus Converter	Alan Mrvica	$0

Converts all sort of units (length, area, volume, pressure, etc.).

First Aid	American Red Cross	$0

Handy first aid reference. An extra tick box to show your dedication to field safety!

Printer Pro	Readdle	$6.99

Send files straight from an iPad to a WIFI-enabled printer.

Mineral Database	Tasa Graphic Arts, Inc.	$9.99

Searchable reference database for properties and photos for more than 300 common minerals.

FieldMove Clino	Midland Valley	$4.99

Lightweight, less featured version of FieldMove. No advantage except it will work on iPhones. Listed for completeness only.

GeoID	Engineering Geology & GIS Lab	$5.99

Structural measurement and stereonet app. Does not appear to be supported anymore. Listed for completeness only.

Lambert	Peter Appel	$2.99

Structural measurement and stereonet app. Listed for completeness only.

Purchase & Assembly

Should be straightforward enough. Most of our equipment was bought from online retailers where possible. I found online prices to be more competitive than the "special educational pricing" offered to our University. Assemble the kit according to the layout shown below. Production line-style assembly can help speed up the process. Pay particular attention to Lifeproof case instructions. It may be worth engraving the more expensive components with identifiers and contact info. I clearly and permanently label every component as a separate kit to be sure students do not interchange items or cover up that they lost something (ex: all items in a kit labeled "UCR GeoPad #[n]").

Setup Gmail & Apple Account

The instructor or person who wants to assume responsibility should consider setting up a dedicated email address (Gmail recommended) either for the GeoPads (e.g. UCRGeoPads@gmail.com) or for the specific course they are using them for (e.g. UCRSummerField@gmail.com). Having a dedicated Google account makes sharing files and documents across the free Google products work particularly well (Gmail, Drive, Docs, Sheets, Slides, etc.). Do not make this password accessible to students.

Upon turning on your first iPad, setup will prompt you to enter or create a new Apple account. Create a new account using your dedicated email address as above. Do not make the password accessible to students. When asked to create a four-digit pin code or thumbprint (iPad mini 3 & 4) click on the fine print "no thanks" option since GeoPads used for teaching should not have sensitive information and should be as accessible as possible. To be able to purchase apps you will need to provide credit card information. Because our University does not issue personal or account credit cards, I give the login details to our department purchasing person and have them fill in their credit card details. When I make a purchase I forward on the email receipt to this person, which works well enough. Your situation may be different.

All iPads should use the same Apple login details. This ensures that you only pay for apps once (not per device), and allows you to easily manage and clone a class or organization set of iPads (which later can be customized individually) from one account.

Basemaps

Having a basemap of some description is an essential feature for most mapping applications as it provides reference, location, and can aid in interpretation. Being able to instantly flip between a half-dozen or more imagery types (aerial, topo, geology, lidar hillshade, etc.) greatly extends this ability to interpret while in the field.

FieldMove offers three "built-in" online basemap options selectable from its Layer menu (satellite, road, and terrain maps derived from OpenStreet Map). Field sites rarely have WIFI, which leaves you two options:

(1) Caching. The easy (but limited) way. If these three layer options are sufficient for your mapping needs and the field area is not overly large, you can temporarily "cache" the imagery to the iPad's internal memory. Think of the cache as a rolling temporary memory- once the cache limit is reached the most recently viewed imagery overwrites the older imagery. Google Earth and most web browsers operate similarly. To cache imagery you should zoom on the map to the maximum imagery quality that you desire. Once the imagery for this area is loaded (clearly visible), move to the adjacent area and let that load. Repeat this until you have covered the entire field area. Repeat this procedure with the other imagery types for the same area if desired. Then double-check that when you turn off the WIFI the imagery is still visible (this indicates it is temporarily stored, and will remain stored until you clear the cache or overwrite it by loading other areas after). Note in FieldMove's Settings menu there are relevant options for basemap loading and cache resetting. I usually make sure caching imagery is the last thing I do before heading to the field and then leave my iPad on Airplane Mode.

This method works great as a "quick-and-dirty" option, requiring little time or setup!

(2) Importing. The harder (but more empowering) way. Arguably one of the most important features of FieldMove is the ability to import your own basemaps. For the iOS case described here this means using iTunes as the bridge between your computer and iPad. Note that FieldMove does not currently support vector-based file types for import. Two raster-based file types are supported for importing, GeoTIFF and MBTiles.

GeoTIFF: GeoTIFF is a fairly standard file format which can be read by most GIS software packages including ArcGIS and Google Earth Pro. It is essentially a TIFF image file with georeferencing information embedded in it (projection, coordinate system, extent, etc.). These files are typically easy to generate (e.g. in ArcGIS). A key disadvantage of this file format is the often large file size for map areas and the fact that FieldMove will try to load the entire file at once (not just the portion visible in the current map view). This can lead to slow basemaps load times, especially initially. I would not recommend importing GeoTIFF files larger than about 350MB each.

MBTiles: MBTiles is the preferred file format, though in some cases may require an additional step to prepare (such as converting from a GeoTIFF file). As the name suggests, this single file is actually a database of smaller raster images that are referenced to each other according to a tiled mosaic. This file structure allows you to customize what is visible at different map scales to ensure the best balance of resolution vs. file size, detail vs. clarity. Many web-based map applications use MBTiles for its efficiency such as Google Maps (with slow internet connections you will see the map area load square by square). The advantage of this file format is that only the imagery within the current map view is loaded (and at the appropriate scale), making for much more efficient basemap loading in FieldMove.

MBTiles work off the principal of a map zoom level, which is defined by the width a 256 pixel wide map is in degrees longitude. A tile is a square raster image 256 pixels by 256 pixels. Notice the steep climb of the number of tiles as zoom level grows (and file size correspondingly). Although this means the pixels per meter depend on latitude and the map scale depends on the pixel size/density of the viewing screen. Some generalizations based on maps centered on the equator are provided in the table below. CalTopo supports exporting images to zoom level 16. FieldMove and Move software support basemaps to zoom level 20. It will depend on the type of mapping and applications you require, but generally zoom levels 16-18 work well.

Level	Degree	Area	Pixel Size (m)	~Scale	# Tiles
0	360	whole world	156,412	1:500 million	1
1	180		78,206	1:250 million	4
2	90		39,103	1:150 million	16
3	45		19,551	1:70 million	64
4	22.5		9,776	1:35 million	256
5	11.25		4,888	1:15 million	1,024
6	5.625		2,444	1:10 million	4,096
7	2.813		1,222	1:4 million	16,384
8	1.406		610.984	1:2 million	65,536
9	0.703	wide area	305.492	1:1 million	262,144
10	0.352		152.746	1:500,000	1,048,576
11	0.176	area	76.373	1:250,000	4,194,304
12	0.088		38.187	1:150,000	16,777,216
13	0.044	village or town	19.093	1:70,000	67,108,864
14	0.022		9.547	1:35,000	268,435,456
15	0.011		4.773	1:15,000	1,073,741,824
16	0.005	small road	2.387	1:8,000	4,294,967,296
17	0.003		1.193	1:4,000	17,179,869,184
18	0.001		0.596	1:2,000	68,719,476,736
19	0.0005	airborne lidar	0.298	1:1,000	274,877,906,944
20	0.0003		0.149	1:500	1,099,511,627,776

Sources for different types of basemap imagery are discussed, followed by steps to import the basemaps into the FieldMove app on the iPad.

This is divided into three sections. (1) Georeferenced map sources that are good to go (other than possibly file type conversion). (2) Unreferenced image sources that will require you to manually add georeferencing for use. (3) Bridging software such as ArcMap, TileMill, Move that allow you to georeference images, layer data, and/or convert their file type to GeoTIFF or MBTiles.

Georeferenced Map Sources

CalTopo
CalTopo is an invaluable (free, account recommended) online GIS, which compiles many excellent basemaps and has functionality to efficiently export to the MBTiles format. In my opinion CalTopo is one of the more user-friendly, and underappreciated resources on this list (hence my longer explanation). Although beyond the basemap discussion here, CalTopo allows you to build your own maps online, import/export/create point, line, and polygon data, collaboratively edit maps, and offers many analytical features (measuring tool, create a viewshed, create a profile view, calculate sun exposure, and calculate terrain statistics for a selected area). Really quite incredible features for a free homegrown piece of work and I highly recommend exploring CalTopo's many capabilities! For frequent users I recommend a Pro account, highly worthwhile at $50/yr. Among other features you can export much larger areas as MBTiles.

Coverage types include shaded USGS topographic maps, satellite orthophotos, shaded relief (hillshade), road maps, historic maps, and terrain maps, and include the ability to overlay contours, slope shading, land management data, fire history data, as well as current weather, water, and snow data. Coverage areas are typically complete across the United States, with some data (topo, etc.) available for Canada and New Zealand. Google layers will work globally.

Due to licensing restrictions it is not possible to export Google or SNOTEL layers, but all others can readily be exported to MBTiles format. This process is walked through below:

(1) Setup. Navigate and zoom to desired field area. Select the desired layer or combination of layers from the left column or drop down menu in the top right corner (mouse over text there, click on text right of "Base Layer" to select, add additional layers as desired, select checkboxes below as needed.

(2) Export. Once you have the desired basemap in view (+/- overlaid data), mouseover "Print" from the top toolbar and then click on "Download KMZ or MBTiles File". This opens a new window or tab in your browser which should have a red rectangle with arrows in the corner (export area). Click-and-drag an arrow on the corner of the rectangle to adjust the area to be exported. Notice because of the tiled nature of the data you may have to download a slightly larger area than targeted for full coverage. On the left size is an option to select the desired target zoom. The highest export option is likely to be "16 1:12k", which is what I would select unless I am worried about file size. When ready, click on "Download MBTiles" to have Caltopo prepare to download the file to your

computer. Once downloaded I would recommend immediately renaming the file something meaningful so you can distinguish it from other files you create (e.g. Hill40ftContUCRcampus.mbtiles; you cannot rename them once they are sent to the iPad).

* Hint: If you want to make the map area clear to students and avoid them walking out of it, add a polygon defining the map area before exporting.

(3) Import. Use directions below to import the created MBTiles file(s) into the FieldMove directory via iTunes.

Site: http://www.caltopo.com
How-To: http://help.caltopo.com/kb

OpenTopography

OpenTopography (free, account recommended) specializes in access to high resolution topographic data, especially publicly-funded airborne lidar data. In addition to raw point cloud data download (for advanced users), there is functionality to have OpenTopography process KML (Google Earth) and GeoTIFF files for you. Current high resolution coverage is mostly limited to specific areas in the United States, but global 90m Shuttle Radar Topography Mission (SRTM) data is also available. The site also features excellent tools and tutorials to support topographic analysis.

Data: http://opentopo.sdsc.edu/datasets
How-To: http://www.opentopography.org/learn

Koordinates

Koordinates (free, account required) is a useful clearinghouse for geospatial data. New Zealand, United States, Canada, and Australia are best represented but new data seems to be added all the time. Vector datasets will need to be converted to raster using a different program.

Data: https://koordinates.com/data/
How-To: https://help.koordinates.com/using-data/

EarthExplorer

EarthExplorer (free, account required) is USGS's main search and download system for orthophotos, elevation data, elevation data, land cover data, and diverse satellite imagery. If you know exactly what it is you are looking for (or have the time to browse), this is a good way to get it. In most cases it will be left up to you to convert the data to a GeoTIFF or MBTile.

Website: http://earthexplorer.usgs.gov/
How-To: https://lta.cr.usgs.gov/ee_tutorial_search_criteria

The National Map

The National Map (free, account required) is USGS's outlet for topographic data (specifically as USGS topographic maps and elevation data). In most cases you will need to convert the data after download.

Website: https://viewer.nationalmap.gov/launch/
How-To: http://training.usgs.gov/TEL/TheNationalMap/TNM-TEL-Index.html

TopoView

TopoView (free, no account required) is yet another USGS outlet for topographic maps. I have found their server to be rather slow at times, but otherwise it has an excellent interface for searching an area for published USGS topographic maps of different ages. It offers the option to download all maps in a GeoTIFF file format. Since the file sizes are relatively small (10-20MB) you do not really even need to convert them to MBTiles. Easy!

Website: http://ngmdb.usgs.gov/maps/topoview/viewer/#4/40.00/-107.51

How-To: https://www.youtube.com/watch?v=kOpe3WXsZrQ

Unreferenced Map Sources

MapView

MapView (free, no account needed) is USGS's admirable attempt to create a United States-wide mosaic of geologic maps with an underlying catalog of geologic map-related resources. This veritable hodgepodge displays a single geologic map image for everywhere in the U.S. I have found most of the maps in view (at least in areas I am interested in) are not readily downloadable and are not the most up to date geologic maps available. Clicking on the "List Pubs in View" tool opens up a handy reference list of resources relevant to that area and includes links to downloads and GIS data where available. Often I will resort to screen grabbing an image (PrtScn) and then crudely georeferencing the cropped image in ArcGIS, which is certainly better than nothing.

Website: http://ngmdb.usgs.gov/maps/mapview/

More Info: http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

Google Earth Pro

Google Earth Pro (free!) is rather restrictive when it comes to directly exporting georeferenced aerial imagery (likely related to the varied data sources), but there is a manual workaround to utilize its high resolution imagery. First go to "Tools>Options…" and then set the Elevation Exaggeration to its minimum (0.01). Be sure your view is vertical and N is up. Click on the Time Slider icon to flip through the available imagery and select the one that is the best for your purpose. "File>Save>Save Image…" opens up image exporting options. Uncheck all the overlays and set resolution to Maximum (4800 x 2916 pixels). If you need to cover a larger area then use the arrow keys to scroll and collect adjacent images in a grid pattern. You can then stitch these into one large image in Photoshop or similar photo-stitching software and then manually georeference the image in ArcMap. There are third party programs and scripts to automate this process, but none I have yet found worth the trouble or expense.

Download: https://www.google.com/earth/download/gep/agree.html

How-To: https://www.google.com/earth/learn/

ArcGIS Earth

ArcGIS Earth (free!) is ESRI's Google Earth knockoff. This is a relatively new offering (born 2016) that I admittedly have only played around with a little, but is worth the download and

keeping an eye on as active development continues. So far I have found it to be faster and more stable than Google Earth (but less featured). It's handy for quick viewing of KMZ files and its ability to readily import your own terrain meshes. The licensed ESRI imagery in many cases is different than Google's so it's worth checking both.

Download: http://www.esri.com/software/arcgis-earth

How-To: http://doc.arcgis.com/en/arcgis-earth/

*** This is an incomplete list and only contains a few of my favorites. Email me if you think something should be added!

Map Layer Preparation & Conversion Software

*** Here I use the term "bridging software" to describe programs that allow preparation and export of map layers from raw sources to the georeferenced file formats accepted by FieldMove (GeoTIFF, MBTiles).

Caltopo

Caltopo (described above) is quite handy in that it allows you to import GPX (Garmin GPS file) or KML (Google Earth) files (both vector-based). You can overlay this data (plus easily create new points, paths and polygons in CalTopo), then underlay it with a selection of their imagery and data, then export all these layers together as a MBTiles file. This will rasterize the vector data which will pixelate the view, but this is still a convenient option. Zoom levels up to 16 (1:12,000; 2.4m pixels) are supported.

Move

Move (free with academic license) is Midland Valley's core application of its full featured 3D geologic software suite designed for geoscientists and engineers. It is capable of loading many geospatial file types and exporting as MBTiles files as well as georeferencing images without geospatial information. Zoom levels to 20 (1:564; 0.15m pixels) are supported. You will need to create an account, request a one-year academic license, and sign an agreement. This program gives maximum functionality to project data exported from FieldMove (kinematic analysis, cross sections, etc.) so is worth exploring.

Software: http://www.mve.com/software/move

Exporting to MBTiles:

www.mve.com/filemanager/docs/move-feature/Augusts_Move_Feature_-_Creating_Basemaps_for_FieldMove_and_FieldMove_Clino.pdf

TileMill

TileMill (free!, replaced by more extensive MapBox Studio) is a lightweight program capable of importing CSV, ESRI shapefile, KML, and GeoTIFF files (among others) and exporting them as MBTiles. Abbreviated workflow: Create a New Project, click Layer symbol in bottom left, import file(s) using Add Layer, click Export>MBTiles in top right, select desired area to

export/filename/zoom levels/etc., Export! Exporting can take a while depending on file size. Not too shabby.

Download: https://www.mapbox.com/tilemill/

How-To: https://www.mapbox.com/tilemill/docs/crashcourse/introduction/

ArcMap

ArcMap ($$) is the main desktop mapping program of ESRI's ArcGIS software package and is a whole world unto itself. A full description is beyond the scope of this webpage but it accepts a wide variety of file types, allows data manipulation and exporting as a GeoTIFF. Currently it cannot directly export MBTiles. I use ArcMap to manually georeference geologic maps or aerial photos and then export as GeoTIFFs.

ESRI Tutorial:

http://help.arcgis.com/En/Arcgisdesktop/10.0/Help/index.html#//009t000000mq000000

Texas A&M University Library Tutorial: https://www.youtube.com/watch?v=PHtxbpboDro

Web Map Academy: https://www.youtube.com/watch?v=BC8kJqWY3Gs

There are plenty of other full-featured desktop GIS programs including open source GRASS GIS and QGIS that could easily be utilized instead for basemap preparation.

Importing Basemaps to FieldMove

Click on the link below to download Midland Valley's guide to preparing and importing basemaps. Notice this includes an explanation of how to import into Android and Windows devices as well as iOS. For iPads, a device with iTunes must be used to transfer basemap data. (1) Connect the iPad to the computer and open iTunes. (2) Click on the symbol in the top left menu area denoting the iPad. Click on the "Apps" menu on the left sidebar. The screen that comes up is confusing as it has three separate scroll windows. Click and drag the far right scroll bar until the second heading "File Sharing" is visible. Within the "Apps" list you should see "FieldMove". Click on it to open the folder for "FieldMove Documents". (3) Drag-and-drop your GeoTIFF and/or MBTiles files into this root folder (alternatively you can use the "Add File…" button at the bottom of the window. You should see a status bar at the top of the iTunes window showing progress. When the bar is gone and replaced by the Apple logo the transfer is complete. When you are done, "eject" the iPad using the eject symbol in the left menu. (4) The final step is to open FieldMove on the iPad, go to the desired project, and then click "Import" under the Layer menu. If all went well you should see a prompt that it loaded successfully.

Midland Valley's overview guide:

www.mve.com/filemanager/docs/move-feature/Augusts_Move_Feature_-_Creating_Basemaps_for_FieldMove_and_FieldMove_Clino.pdf

Cloning a Set of Identical iPads

For use in a class or for an organization. Exact instructions may vary as Apple's software inevitably is updated. These directions work as of September 2016.

(1) Setup "master" GeoPad with apps/layout/files that you wish to clone to all GeoPads. This means you should have all data you wish to give the students (basemaps, journal articles, etc.) preloaded before starting to clone the devices. Think carefully about how to arrange according to priority. I hide useless Apple bloatware deep into folders. Add a nice geological background image or your department logo to the desktop. Note that the "master" GeoPad should not necessarily be the instructor's GeoPad (if you want to have your own data, previous year's work, geological maps, music collection, and other things that you might not want on the students' GeoPads).

(2) Connect "master" iPad to iTunes. If you are using FieldMove with external map layers (Geotiff or mbtile formats) drag-and-drop them into the app's folder under File Sharing under the iPad in iTunes. Once iPad is 100% ready to go, use Back Up Now to save a copy of the master iPad to the computer. Put master iPad aside. The following directions pertain to the iPad to be cloned.

(3) Turn on "clone" iPad. Run through iPad setup (English, US, wifi setup*, Enable Location Services, Setup as New iPad**, Sign In With Your [course] Apple ID, Agree, Don't Use iCloud, Don't Add Passcode, Use Siri, Don't Send Diagnostics, Get Started) *We use 90-day guest accounts to our university's wifi (1 per iPad) to keep students from logging in with their personal details. **You cannot go straight to "Backup" at this point if the Backup iOS version is different than the factory shipped iOS version.

(4) On clone iPad go to Settings, then General, then Software Update. Download and Install latest version and Agree. This could take sometime (multitask if necessary). Run through iPad setup again! (see Step 3)

(5) On the iPad go to Settings, then iCloud, then Find My iPad. Turn off Find My iPad (log-in required to confirm).

(6) Connect clone iPad to computer. Allow iPad access to computer and tell iPad it trusts the computer. Select "Restore from this backup" and be sure your master iPad backup is selected.

(7) After restoring you'll have to setup the iPad yet again! Sometimes the wifi log-in seems to be automatically entered wrong. Go to Settings, Wifi, select your wifi, and Forget This Network. Re-select and re-enter wifi log-in details. At this point you should be prompted for Apple verification. Click Settings on the pop-up and enter your account password. Enter it again if you want to sign-in to the iTunes Store. It's now OK to disconnect from the computer. Via the wifi connection the iPad will begin populating the apps onto your home screens. If the iOS updates added unwanted bloatware (Garage Band, Keynote, etc.) you can long press on them, the select the "x" to delete them. Loading of apps could take 5 minutes or so. This is a good time to charge your iPad to full battery. Also don't forget to name your iPad something unique (e.g. "UCR Earth Sciences GeoPad #3") under Settings, then General, then About.

(8) The last step may be to go to the App Store, then Updates, then update your apps to the latest version if they were not already (ideally they already are).

(9) Repeat Steps 3 to 8 for any additional iPad to be cloned. Once you get the hang of it you can get them through the production line at about five minutes each.

Using a Bad Elf GPS

The cellular version of the iPad Mini 2 has an internal A-GPS/GLONASS receiver that is capable of about 5m positional accuracy (perhaps sufficient for teaching exercises but not research or industrial applications). The Bad Elf GNSS Surveyor is capable of 1m stationary accuracy while in the field (SBAS+PPP) and 10-50cm accuracy with post-processing of raw data (RINEX files). This small device connects remotely to the iPad by bluetooth, overriding the iPad's internal GPS with the Bad Elf's more accurate measurements. The Bad Elf app is a user-friendly utility that helps manage the connection and functionality. Some students preferred to wear the GPS around their neck on a lanyard. I preferred to leave it in the top pocket on my backpack where it was out of the way but had a good view of the sky. I will consider expanding this section if there is demand, but I think the links below do an adequate job of explaining the advantages and procedures.

Bad Elf user guide:
https://cdn.shopify.com/s/files/1/0227/2953/files/UserGuide-BE-GPS-3300-20140517.pdf?1710

Obtaining 1m accuracy in the field:
http://bad-elf.com/blogs/bad-elf/announcement-bad-elf-supports-high-accuracy-location-in-esri-collector

Sub-1m accuracy through post-processing:
https://bad-elf.com/blogs/bad-elf/announcement-new-bad-elf-app-and-firmware-for-the-gnss-surveyor-accessory-post-processing-and-dgps-support

Bad Elf educational discounts:
https://bad-elf.com/blogs/bad-elf/using-gps-in-education

Using FieldMove

This is typically the point at which I start involving undergraduates in the workflow. The GeoPads are ready to go with apps and basemaps preloaded to save time and I just provide a brief explanation of what I did to set it up (download apps, preload data). I consider this last point important as it ensures they have gained a marketable skill that they can setup for an employer or graduate advisor from the start.

Midland Valley has put together a handy User Guide for FieldMove, which includes clear export instructions: http://www.mve.com/media/documents/FieldMove_User_Guide.pdf

Thankfully the FieldMove app is gracefully sleek and intuitive in its organization, which spares me a more detailed walkthrough here. Essentially the map takes up most of the screen real estate with GPS status shown on the top bar and most of the functionality tidily organized on an

expandable sidebar (symbols in descending order: Expand Side Panel, Project Properties, Map Layers, Measurements, Drawing Tools, Stereonet, Notebook/Photos, Export, Help). Pinch to zoom the map, drag to move. You'll pick it up in a few minutes!

Exporting Data

Exporting data created in FieldMove is a very straightforward process. All data created in FieldMove are able to be exported including vector-based point/line/polygon data, raster-based photographs (including annotations), and text-based note/measurement data (basemaps are not exported with the GeoPad created data).

For the simplest class exercises we have had students export .kmz files that they submit to a folder in a course Google Drive folder. This is intuitive for the students and easiest for the instructors to grade by opening the KMZ files in Google Earth. When loaded in Google Earth much of the visualization of features is preserved (for example structural measurements will have the correct symbol and orientation; linework colors will be preserved). You can choose to have students (a) submit their raw exported KMZ file immediately on return from the field, (b) give them an opportunity to edit features directly on the iPad, or (c) have the students edit and organize the file in Google Earth. You may wish to have students remove their geotagged field notes and field photographs from the final submitted map or leave them in and grade them as part of the assignment.

For professional products, the more involved procedure of pushing the data to Move or ArcGIS may be more appropriate. The basic steps for exporting are as follows:

(1) In FieldMove click on the "three horizontal line" menu option, then the Export symbol. Here you can select which of three file types you wish to export: (1) .mve, the proprietary database-like project format of Midland Valley's Move program, (2) .kmz, the proprietary database-like format for Google Earth, and (3) .csv, a comma separated text file (this option actually exports several output files sorted by data type such as line.csv, plane.csv, note.csv). Choose .mve if you plan to work with Move (a full feature geological software suite allowing the creation of geologically valid 3D models and cross sections, most advanced option). Choose .kmz for quick viewing in Google Earth (easiest option). Choose .csv if you want quick access to notes or structural data. Choose either .kmz or .csv if you are planning to move the data to a third party GIS system, such as ArcGIS.

(2) After the "Export Successful" message appears the file will be created and sit in FieldMove's file sharing folder on the iPad. There are two main ways to access the created file:
  (a) By clicking on the Share button you will have the option of (i) exporting to another Apple device using AirDrop, (ii) emailing the file to yourself, or (iii) file sharing it to a Dropbox or Google Drive folder.
  (b) Alternatively you can connect the GeoPad to a laptop or desktop computer and open iTunes. Select the iPad icon, then click on the Apps menu, then scroll down

to the File Sharing menu, and select FieldMove. You should see all your created files ready to be dragged-and-dropped to you computer desktop.

(3) If necessary convert the files to the desired file type. KMZs can be resaved as KMLs in Google Earth (this will strip the field photos). A couple methods to convert KMZ to file geodatabases (.gdb) or KML files to ArcGIS shapefiles (.shp) are described at links below.

Midland Valley has put together a handy user guide for FieldMove, which includes clear export instructions: http://www.mve.com/media/documents/FieldMove_User_Guide.pdf

Info on AirDrop: https://support.apple.com/en-us/HT204144

Opening KMZ in ArcMap: http://thetalkinggeek.com/opening-kmz-kml-files-in-arcmap/

Convert KML to SHP online: http://www.zonums.com/online/kml2shp.php

Convert KML to LYR ArcGIS tool:
http://pro.arcgis.com/en/pro-app/tool-reference/conversion/kml-to-layer.htm

UGeorgia Guide to convert KML to SHP: www.uga.edu/gpshort/instructions/GIS_Convertin Google Earth klm to ArcMap shp.pdf

Post-Export Manipulation

See the Research page for a limited discussion of where you can push your field data once back in the office (GIS, 3D mapping, stereonets, etc.). I will aim to add more content as time and experimentation allow.

Teaching Implementation
/teaching

Undergraduate Students

Implementation
This GeoPad system was first implemented in UCR's 2016 four-week GEO 102A-B Summer Field Geology course, which was the final course many of the eleven undergraduate students took before graduating. The course is designed to be a capstone culmination of their degree, with prerequisite courses including Petrology, Sedimentology, Structural Geology, and two field mapping courses (which themselves have prerequisites). While traditional field mapping methods played a strong role in the Summer Field Geology course, we involved use of the tablets in about half of the field projects. The field projects were variable in scope and goals, and lasted one to eight days each.

Orientation
We issued a complete kit to each student about a month before leaving for summer field, explaining the basic concept and going over some of the setup in a one-hour meeting. This was then followed by a half-day field excursion to give the students the opportunity to create a simplified geologic map (we chose to keep this an ungraded exercise). One of the first exercises we did was to go to a large, dipping bedding plane, have each person in the class take a strike-and-dip of bedding using their Brunton compasses (which I recorded in my field notebook), and then had each person in the class take the same measurement using their iPad (again I recorded). This was a good confidence boosting exercise for both the instructor and class, as a shotgun-blast of compass-collected data (attributed to student measuring error not the compass directly) shrunk to a +/- 2 degree iPad-collected data cluster.

First Project
We reissued the iPad kits to the students about 1.5 weeks into the Summer Field course, after they completed a large traditional mapping project (Eastern California's classic Poleta Folds). The focus of this project was mapping the bedrock geology in a structural and stratigraphically challenging setting with very well-exposed outcrop. The first digital exercise assigned to the students was a 0.5 mi x 1.5 mi region immediately south of the area they had just mapped.

The students had a half day to interpret the geology remotely from the field classroom (drawing faults, folds and unit contacts from aerial and lidar imagery), one full day in the field to map as much as they could, and then an evening to refine their map before submission. By having their first digital project in a geological environment they were well acquainted with (climate, terrain, geology), the students could focus on learning to use the iPads effectively. This was a unique and effective exercise in several ways: (1) the students learned they could efficiently map the geology of an area remotely from high quality imagery if they were equipped with local experience and background knowledge of what they could expect to find, (2) the students were exposed to the real world scenario of not having as much time on a project as you would ideally

like, and (3) the students could form a more direct comparison of the advantages and disadvantages of traditional field mapping methods compared to current digital mapping methods since they were mapping a new region but with familiar stratigraphy and structures (they found that they could take more measurements and cover more ground in less time, but found screen glare and glitches to be new challenges).

Although three or more field days could have easily been spent mapping this region, both I and the students were impressed with what they were able to map in 1.5 days. Student feedback suggested this project served as an effective bridge into the digital field mapping world.

Other Projects
- A 2-day project focusing on mapping metamorphic rocks and their relationships to a pluton in an alpine setting (Crooked Creek, White Mountains, CA)
- A 1-day project focusing on mapping glacial geomorphic features of multiple ages (Convict Lake, Long Valley, CA).
- A 2-day project focusing on mapping multiply-deformed metamorphic roof pendant rocks and their relationships to intrusive rocks in a forested setting (Gull Lake, Eastern Sierras, CA).
- A 2-day project focusing on mapping volcanic lithofacies, vent locations, and former lake shores on an emergent subaqueous-subaerial Surtseyan volcanic edifice (Black Point, Mono Lake, CA).
- A 1-day project focusing on analyzing rock slope stability of blasted roadcuts along a gated access road (Owens River Gorge, CA). The iPads were used to efficiently take structural measurements but not really for mapping.

For simplicity we had the Summer Field students make all their finishing touches within FieldMove (or Google Earth if they preferred), then export their project as a KMZ, which was shared to a Google Drive folder by the deadline. I then created a folder in Google Earth on my PC, which allowed me to easily order the student projects from best to worst. By layering several at a time it was very easy to check for cheating.

Assessment

To assess the student projects I used a rubric I created with the above workflow in mind (adapted for all editing to be done on the GeoPad and quick export to a .kmz file). Note that many things relevant to paper or digitally drafted maps are not relevant to digital projects submitted in .kmz format (North arrow, declination, scale, title, etc.). "Neatness" and "accuracy" need to be considered based on a desired map scale. The ability to readily layer multiple student maps in Google Earth provides a very fair means of directly assessing the relative quality of student maps. Potential biases driven by handwriting style or coloring quality are also eliminated.

The digital field mapping project rubric is available here:

This rubric is modified after one used by Miami University for their capstone field course and publicly available on SERC's website:
(http://serc.carleton.edu/NAGTWorkshops/departments/degree_programs/instruments/miami_capstone_rubric.html)

Cheating

Instinct might tell you that a subset of students will latch on to the opportunity to download data and claim it as their own. This concern may be genuine if you are mapping in an area used by other schools. However, if you chose to map in an area effectively only used by your class, you can easily maintain a KMZ database of all past years' student projects. Because you can readily layer as many maps as you want in Google Earth (and check for repeated or copied elements), you can check for cheating more quantitatively and with less effort compared to paper maps. This took only a few minutes for me to check an entire class for potential cheating.

Other Ideas

Professional Map Draft
If you wanted to take the projects further (e.g. have more time available in a classroom setting) you could have the students examine their field data in Move and use it to create balanced cross sections, or take their data to ArcGIS or Adobe Illustrator to do a final "published map style" draft.

Tiled Project
This digital field mapping system is well suited for teaching students to map in a quadrangle-style where groups of 2-3 students map a rectangular region which abuts regions other students in the course must map. To do this you can pre-load the different "quadrangle" boundaries onto a basemap or have the students draw it on later. At the end of the project the students must submit a final detailed map of their sub-region, and a smaller scale map where they aggregate the entire class' tiled data (made available in a shared Google Drive folder) into a "seamless" (and inevitably simplified) map covering the entire student mapped area. This will teach them about how many professional geologic maps are made, how different geologists place different emphasis on the features they see and map, the challenges in compiling maps from different sources, and how large-scale field mapping is often simplified for clarity on small-scale final maps.

A variation on this exercise would be to give students a geologic map with a region extracted as a basemap, and task the students to map the extracted region in the same style of the existing geologic map. Be sure it is not a map they could easily find though!

Crowdsourced Data
The tablets enable collection of structural data at considerably greater efficiency and accuracy than students are capable of with a Brunton compass. This allows them to accumulate a vast

dataset in a very short time in the field and then pool their data back in the classroom (strike-and-dips, fault kinematic data, paleocurrent data, etc). Ideally in the future the AirDrop functionality would allow direct import into different devices' FieldMove program.

Scalability
In contrast to paper maps which must always have a fixed scale, the ability to instantly pinch your way between any scales (say 1:500 and 1:24,000) on a digital map means that you can readily teach students about the importance of scale in digital mapping. If you select a field area that has patchy outcrop overall but some very revealing mappable outcrops, you can emphasize the importance of mapping these outcrops in detail to better understand and map the less exposed regional geology. This works well in structural scenarios where small features mimic large (e.g. parasitic folds to a regional fold, secondary faults to a larger fault). The students had to learn this technique to some extent in our Black Point exercise where relationships between volcanic lithofacies were exposed in a few key cliff sections.

Building Basemaps with UAVs
The field mapping exercise could be taken further (and expanded in duration) by teaching students how to use UAV (a.k.a. drone) photographs and structure from motion (SfM) photogrammetry techniques to create their own basemaps (high-resolution orthophotographs, hillshades, and contours). The exact details are beyond the scope of this website but essentially this would require (1) one (or more) field sessions to collect the photos and GPS control points, (2) a lab session to process the data in SfM/GIS programs (e.g., AgiSoft PhotoScan, ArcGIS) and export products to the iPads, (3) one (or more) field sessions mapping on the basemaps in FieldMove, and (4) potentially another lab session (or several) to export and manipulate the data. This is a workflow likely to become much more prevalent in industry and research due to the relatively low cost and ease of use. This concept was demonstrated successfully over a two-day field trip in my Fall 2016 graduate-level Modern Field and Visualization Techniques course (to the delightfully unvegetated and wonderfully exposed Rainbow Basin in the Mojave Desert). Exporting orthomosaics as MBTiles in PhotoScan (with or without contours) can easily be uploaded to the GeoPads in the field to allow students to map on it immediately. If you are really organized, willing to submit to the positional accuracy of the UAV's GPS (~3-4 m), and bring a laptop in the field for processing, it is possible to be able to go through this whole workflow with the students in less than an hour! The resolution of the data was considerably better than the ~5 pts/m2 point density in the 2007 EarthScope airborne lidar data collected for the same area. This greatly impressed the students!

Graduate Students

In Fall 2016 I introduced the GeoPad system in a newly designed graduate-level Modern Field and Visualization Techniques course. I advertised and recruited the 12+ students from our department and beyond (Environmental Sciences, Anthropology) ensuring diverse backgrounds in geology, geophysics, paleontology, environmental sciences, and anthropology. For this course students generated their own basemaps and then utilized them in the field. The course

also included an introduction to landscape change detection, post-export data manipulation, and every student had a chance to 3D print a fossil or landscape that they digitally modeled. The graduate students picked up the digital field mapping technology as well as the undergraduates and seemed to produce tidier and more data-rich maps. A personal highlight for me was to see how the intuitiveness of the GeoPads and the FieldMove program enabled archaeologists to quickly pick up the basics and create their first geologic map in less than two full days! They could easily see how the same program and methodology could be utilized for archaeological mapping.

Students' Perspectives

These comments were solicited from 2016 UCR Summer Field Geology students by anonymous web survey at the end of the course (as part of a much longer 40 question survey about the course). This capstone course was the first time these tablets (and digital field mapping) was introduced to the students. The students used the tablets for six 1-2 day mapping activities (in addition to projects utilizing only traditional mapping techniques). Comments are unedited and appear in their entirety. Generally student responses to using this system were quite positive.

Overall do you feel like using the iPads in the field enhanced your geological understanding and/or mapping efficiency of an area? Did they contribute to the capstone experience?

- It definitely increased efficiency. No time was lost finding your location on the map. The ability to simultaneously look at an aerial photo made placing unit boundaries easier.
- YES! I enjoyed having access to photos and notes in the same place.
- I have mixed feelings over the iPads. Measurements, mapping, and easy access to multiple maps greatly increases the efficiency of an area. However, glitches in the iPads and my preferred time to hand map my units in a geological paper map also leads me to think "old mapping" is still preferred. I do think using a bit of technology did contribute to the capstone experience.
- Yes, I enjoyed the iPads tremendously. They were far more convenient to carry around and take measurements with than the traditional map boards and I do think they enhanced the understanding and mapping efficiency of the various areas.
- There was a moment when everything clicked with the iPads. Before that, I felt like hand mapping was better. After I got the hang of it, I think the ipads proved their worth. They were awesome.
- Yes, mapping efficiency is increased with regards to taking measurements. Also it allows more time to analyze geological stuff, rather than dealing with bulky map boards, colored pencils and compasses. It is convenient to carry.
- I do not feel that the iPads enhanced my geological understanding, but they definitely improved my efficiency. The iPads contributed a major role to the capstone experience.
- I thought they were helpful in that we know where we are. However I paid less attention to where I was because I relied on the GPS. Editing is much easier on the ipad.
- Yes, mapping was much faster with them.
- Certainly helped with efficiency but not necessarily with understanding. aerial photographs were the same as the ipad. They did allow for faster mapping which made the work much more possible in the short time so yes they were highly necessary.
- Yes and yes.

Do you feel like digital field mapping and data collection were worthwhile skills to learn?
- Yes
- Yes, although doing a little more traditional topo mapping would have been nice.
- Yes, data collection is more efficient in digital field mapping, and for years to come I am confident these will be worthwhile skills to learn.
- Yes, I think the future of geology will be based on digital data collection (for good or bad) and they are very useful skills to learn.
- Yes, they are very worthwhile. I imagine that in the future, it will become more of the go-to.
- Yes, it improves mapping efficiency
- Yes. Anything that includes newer methods of mapping helps. ie iPad, drones, lidar, etc..
- Definitely.
- Yes
- Most certainly.
- Yes.

Given the choice to map an area with a paper map and compass or an iPad, which would you choose?
- iPad
- Ipad!
- If I had to choose one, the iPad. I honestly believe both are still the best tools to learn as experience as much as possible.
- I would choose an iPad. It as GPS for locating exact positions, is much more convenient to carry, and the paper maps tear and are difficult to correct when mistakes are made (which happens very often).
- I would choose the iPad.
- iPad
- iPad
- Ipad because it is faster. I don't waste time trying to figure out where I am. But figuring out where you are on the map is a great skill to have.
- iPad
- I would choose the Ipad given it's light weight versatile and quick utility and very accurate location notes/photos.
- iPad without a doubt. Despite all its flaws the iPad is an order of magnitude better than a paper map.

Should we have used the iPads less often for projects?
- There were some projects we brought them and they weren't needed on. Gull Lake and the Glacier project we only used the iPads for GPS and note-taking.
- No, but maybe a mix of the two?
- I consider it would be better to use less iPad work in the future.
- No.
- I preferred the ipads.
- No, it was the right amount. iPads should only be used for mapping projects
- No.
- I think we should use the ipad and paper map equally.
- No
- No, I don't think it would have been possible to work as fast.
- No. We should have taught people how to use them more before field camp.

What was your favorite feature?
- Being able to have my photos geotagged was really useful.
- Pictures, feasibility of adding units, and fast measurement taking.

- I like the FieldMove app and its GPS feature, enabling me to locate my position in the field and way around it.
- I liked the overlays you could import. The GPS was very handy. Probably the GPS is the best part--knowing where you are at all times is great.
- Dip and strike measurements, adding geological units, camera
- The GPS. I could spend hours trying to figure out where I am on a paper map, but with the iPad I can focus on mapping.
- The GPS
- Able to take strikes and dips quickly
- The gps location of any and all notes and pictures. I could take a photo of the outcrop with annotation and notes, break off a sample, then take a photo of the sample to know which bed it related to, and take the sample back without marking it with names or whatever more difficult methods i've seen.
- Georeferenced pictures. Amazing. S+D too.

Is there an app you wished the iPad had?
- No
- An app that gave more info on a subject- kind of like a wikipedia app or something. And rock identification for igneous, and metamorphics.
- Not that I know of.
- Not that I can think of.
- I don't think there was anything I felt was missing.
- A better note-taking app
- Any app that could help in identifying a rocks.
- No
- No, everything needed was already downloaded.
- Not really.
- Better map editing software. Something to do cross sections.

What hardware challenges did you encounter? (stylus tip breaking, screen scratching, overheating, etc, etc.) How frequently? Could these have been prevented or minimized with a "you break it you buy it" motto?
- Overheating was a big problem for the geotechnical project. I don't think that could be prevented. I may have been more careful to not have the iPad anywhere near me while hammering off a sample with a "break it you buy it" policy.
- I only encountered a glitch that was fixed with an update. Afterwards, no problems were experienced. People would have definitely been nicer to the iPads if they knew they'd buy it if the break it. But then again, some poeple are just do not know how to take care of anything...
- Stylus tip breaking, and overheating. After I broke the first Stylus tip in a matter of days, I decided not to use it anymore do it high sensitivity and would not help minimize the "you break it you buy it" motto.
- I did not encounter any of these problems for the duration of the field camp.
- Slight scratches on the screen and both stylus tips broke. The ipad kept crashing early on but stopped after week 2 suddenly. The stylus tips are very fragile. I think I took good care of the ipads, but a little more "persuasion" to make sure they come back good doesn't hurt.
- Stylus tip was easily lost, the Lifeproof screen scratched each time dip and strike measurements were taken. Overheating was rare during the entire field camp.
- Both of my stylus tips broke. I do not think that a "you break it you buy it" motto could have prevented this because they were so sensitive. I experienced only minimal overheating and scratching, but these are things that are unavoidable. I don't think that a "you break it you buy it" motto could have prevented this.

- Everything you said above and the GPS turning off randomly. The app crashed on me numerous time. Use the stylus only in the lab not in the field. Definitely you break it you buy it would have made me take care of it more.
- Stylus tip breaking-once screen scratching- a few times resulting in some scratches overheating-various times, but mostly during the geotechnical project Yes, could be prevented by saying that.
- Overheating was never a problem if ipad was not held in the sun and kept in hands properly. It literally never overheated for me so it's overheating is entirely user error. GPS problems if held near electronics or metal. that's really it.
- Stylus tip broke, screen easily scratched, overheated a ton on hot days, short battery life, etc. All these happened a lot. You break you buy it might work but just taking a S+D with the iPads will scratch the case. You can scratch the screen with the stylus even.

What software challenges did you encounter? (features that did not work well, counter-intuitive user interface, glitches, etc, etc.) These I can report to Midland Valley for improvement.

- Just the GPS turning off, especially without saying it was off. Sometimes while using fieldmove, it would continuously prompt me to calibrate.
- Sometimes when I made a new unit I would try to click on it to take a measurement but it recognized it as another unit.
- The GPS turning off instantly and without warning glitch, that is the most annoying part in the software.
- The only challenge I encountered was the stylus not registering on the iPad screen because the screen protector was too thick.
- I would crash to the app selection screen every 5 minutes. That's my only issue. Everything else was manageable.
- Sometimes the GPS got off-track for a few minutes, dip and strike measurements would sometimes get stuck (the measurement would be frozen in black) and the app would need to be restarted. the GPS tracker should show a line connecting the last known position and the current location, as well as a directional indicator for the blue dot
- GPS initially takes me to the wrong location. GPS turns off while mapping.
- The app crashed several times. GPS turns off a lot..
- FieldMove closing down, some of the maps not downloading correctly especially hillshade, and GPS turning off after battery is below a certain percentage.
- Does gps count for software or hardware?
- S+D froze, GPS glitches, crashed a lot, random internet linking, constant recalibration.

My Approach

When teaching students I emphasize the need to create clear and careful notes while in the field and the importance of producing crisp linework that is tidy (it is what they are expected to turn in and are graded on). However, the reality is that my opportunities for fieldwork are so few and far between, and often can involve such hard-to-get-to locations, that **efficiency** is of greatest importance. For me a well-utilized hour in the field is worth ten staring at a computer screen in my office...for better or worse this means staring at a computer screen while in the field too! These days I do *all* field mapping and *most* structural measurements using a GeoPad, as well as brief notes, low priority field photos, and some field sketches. I back up important GPS locations in my paper field notebook and still use it for more involved descriptions or sketches. I always take a digital SLR camera for important photos where the greatest manual control and resolution are crucial. Two other useful tips: (1) I always make sure the time on my phone, GeoPad, camera, GPS, and all other recording electronic devices are perfectly synced so that it is foolproof to correlate times and locations outside of the field. (2) Recording a GPS track all day (takes little battery on a Bad Elf GPS) provides an important backup record of where you were and when, which again can help reconstruct locations of photos and samples taken. Once out of the field I export the field data (mapping, measurements, geotagged notes, etc.) primarily to ArcGIS for further editing and geospatial analysis.

I will aim to add more topics and content with time, but for now I have included a few research-based uses of the GeoPads beyond what is perhaps useful to teach undergraduate students.

Research-Grade GPS Positioning

Cell phones and other consumer-grade GPSs (~3-10 m positional accuracy) are usually sufficiently accurate for student mapping projects, but research applications can demand greater accuracy such as mapping-grade GPS (~1 m accuracy) or survey-grade GPS (~1-10 cm accuracy = $$$ & considerable weight). FieldMove allows for 6 decimal places for its latitudinal and longitudinal measurements, meaning that depending on your latitude it is capable of recording horizontal position to within 11 cm (and vertical positioning to 1 m), sufficient for most field applications other than surveying. To achieve accuracy beyond that you would have to store the positional data outside of FieldMove.

While you could use an external Trimble GPS and manually override the location, the Bad Elf GNSS Surveyor (discussed above) is a handy bluetooth GPS that interfaces very effectively with iPads. This opens up an option to achieve 1 m accuracy in-field by connecting to an NTRIP feed for real-time differential GPS corrections, or to record raw satellite data (as a RINEX file) to enable later post-processing of important locations. With a location occupation time of 10-15

minutes it is possible to post-process for 20-50 cm accuracy with a Bad Elf. So far I have trialed the California Real Time Network (no success) and UNAVCO's real-time GPS data broadcast.

Below are some resources to get you started:
https://bad-elf.com/blogs/bad-elf/announcement-bad-elf-supports-high-accuracy-location-in-esri-collector
https://bad-elf.com/blogs/bad-elf/announcement-new-bad-elf-app-and-firmware-for-the-gnss-surveyor-accessory-post-processing-and-dgps-support
https://bad-elf.com/pages/post-processing-gnss-data-with-rtklib-introduction
http://www.unavco.org/data/gps-gnss/real-time/real-time.html

Tethering a GeoPad to a Cell Phone

Few people (academics at least) will want to buy a dedicated phone and data service plan for their GeoPads but it is possible to "tether" the GeoPad to a smartphone that has coverage and is supported. Essentially this consists of using your phone as a personal internet hotspot by linking it remotely to your iPad by wifi or bluetooth connection. I would consider this one step too far for teaching uses but for researchers it has benefits. The main advantages are in-field access to online imagery (for example provided by FieldMove and GaiaGPS) and the ability to connect to a real-time NTRIP feed to obtain in-field GPS position accuracy of 1 m with a Bad Elf GNSS Surveyor (see above). A Google search should pull in specific information on hotspot tethering for your make of phone and service provider.

Theodolite for Surface Exposure Dating

Although far from its intended use, I have found that the Theodolite app is perfectly designed to efficiently record and calculate topographic shielding when collecting samples for cosmogenic surface exposure dating (an important technique in geomorphology). The important measurements are the inclination of the horizon at 15-45 degree increments and the approximate position and altitude, which allow calculation of the cosmic ray shielding factor crucial for exposure age determination. Theodolite overlays all this necessary data onto a photo! Just point the crosshairs at the horizon and press the save button. In contrast to the time-consuming analog method of recording bearings by compass and inclinometer, the images reliably preserve the horizon angle, azimuth, GPS location, altitude, and date, as well as providing a complete visual context for the collected sample (useful to document stability of the site, potential for fires, man-made disturbances, etc.). In about two minutes I can complete the necessary field measurements that would traditionally have taken me closer to ten or fifteen minutes. Bonus tip: I will use this program's calibration tools if the compass measurements seem to be acting up in FieldMove.

Post-Export Data Manipulation

Google Earth

As discussed on the Teaching page, exporting your field data to Google Earth (.kmz) is the quickest and easiest way to view, edit, and share data. From my experience the files can cause Google Earth to crash and so having it backed up in another format is wise.

ArcGIS

Google Earth may be a useful stopping point for many undergraduate student projects but graduate students or other researchers may wish to push their field data to ArcGIS or other GIS softwares (GRASS & QGIS for free open-source options). Using the Export feature in FieldMove you can push data to ArcGIS in two ways:

(1) Convert the exported .kmz file (best for bulk import of data)
- Opening KMZ in ArcMap: http://thetalkinggeek.com/opening-kmz-kml-files-in-arcmap/
- Convert KML to SHP online: http://www.zonums.com/online/kml2shp.php
- Convert KML to LYR ArcGIS tool: http://pro.arcgis.com/en/pro-app/tool-reference/conversion/kml-to-layer.htm
- UGeorgia Guide to convert KML to SHP: www.uga.edu/gpshort/instructions/GIS_Convertin Google Earth klm to ArcMap shp.pdf

(2) Convert the exported .csv files (best if you want to separate out point, line, polygon, planar measurements, note data, etc.)
- Use Add XY Data to import CSV: http://support.esri.com/technical-article/000012745

Move

The third Export option is a .mve file. I have only just begun to experiment with "moving" data from FieldMove to Move, but this is essentially what FieldMove was designed to do. Move is a full feature structural geology software suite allowing the creation of geologically valid 2D/3D kinematic models and cross sections, fault slip analyses, stress analyses, etc. I will share my experiences with Move as they develop.

For an overview of the software visit Midland Valley's website: https://www.mve.com/software/move

To promote its use, Midland Valley currently offers free academic licenses for Move: www.mve.com/filemanager/images/software/2014/.../Move2014.2_LicensingGuide.pdf

Journal and book references are organized by year rather than author to highlight the progression of technology and implementation. Let me know if I am missing something important!

Websites:

SERC Teaching with GeoPads
http://serc.carleton.edu/research_education/geopad/index.html

Pavlis (UTEP) Digital Mapping website
http://www.geo.utep.edu/pub/pavlis/digitalmappingwebpages/

Wikipedia, Digital geologic mapping
https://en.wikipedia.org/wiki/Digital_geologic_mapping

Has digital field mapping finally arrived? - an industry application
http://www.orefind.com/blog/orefind_blog/2016/07/10/has-digital-field-mapping-finally-arrived-

Export Tools & Tutorials:

FieldMove Tutorials
http://www.mve.com/digital-mapping/documentation
www.mve.com/filemanager/docs/move-feature/Augusts_Move_Feature_-_Creating_Basemaps_for_FieldMove_and_FieldMove_Clino.pdf

Convert KML to SHP online
http://www.zonums.com/online/kml2shp.php

Convert KML to LYR ArcGIS tool
http://pro.arcgis.com/en/pro-app/tool-reference/conversion/kml-to-layer.htm

UGeorgia Guide to convert KML to SHP
www.uga.edu/gpshort/instructions/GIS_Convertin Google Earth klm to ArcMap shp.pdf

Using AirDrop to share between iPads in the field
https://support.apple.com/en-us/HT204144

Data Sources:

CalTopo
Site: http://www.caltopo.com

How-To: http://help.caltopo.com/kb

OpenTopography
Data: http://opentopo.sdsc.edu/datasets
How-To: http://www.opentopography.org/learn

Koordinates
Data: https://koordinates.com/data/
How-To: https://help.koordinates.com/using-data/

USGS Earth Explorer
Website: http://earthexplorer.usgs.gov/
How-To: https://lta.cr.usgs.gov/ee_tutorial_search_criteria

USGS The National Map
Website: https://viewer.nationalmap.gov/launch/
How-To: http://training.usgs.gov/TEL/TheNationalMap/TNM-TEL-Index.html

USGS TopoView
Website: http://ngmdb.usgs.gov/maps/topoview/viewer/#4/40.00/-107.51
How-To: https://www.youtube.com/watch?v=kOpe3WXsZrQ

USGS MapView
Website: http://ngmdb.usgs.gov/maps/mapview/
More Info: http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

Google Earth Pro
Download: https://www.google.com/earth/download/gep/agree.html
How-To: https://www.google.com/earth/learn/

ArcGIS Earth
Download: http://www.esri.com/software/arcgis-earth
How-To: http://doc.arcgis.com/en/arcgis-earth/

Software:

iTunes: https://www.apple.com/itunes/download/
Move: http://www.mve.com/software/move
TileMill: https://www.mapbox.com/tilemill/
ArcGIS: https://www.arcgis.com/features/index.html
GRASS GIS: https://grass.osgeo.org/
QGIS: http://www.qgis.org/en/site/
AgiSoft PhotoScan: http://www.agisoft.com/downloads/installer/

VisualSFM: http://ccwu.me/vsfm/

Progress in Digital Geologic Field Mapping:

Jordan, C.J. and B. Napier (2015) Developing digital fieldwork technologies at the British Geological Survey. in Bowman, M., Smyth, H. R., Good, T. R., Passey, S. R., Hirst, J. P. P. & Jordan, C. J. (eds) The Value of Outcrop Studies in Reducing Subsurface Uncertainty and Risk in Hydrocarbon Exploration and Production. Geological Society, London, Special Publications, v. 436, 11 p, doi: 10.1144/SP436.6

Whitmeyer, S.J. (2012) Community mapping in geology education and research: How digital field methods empower student creation of accurate geologic maps, GSA Special Paper 486, p. 171-174, doi: 0.1130/2012.2486(27)

Whitmeyer, S.J., Nicoletti, J., and D.G. De Paor (2010) The digital revolution in geologic mapping. GSA Today, v. 20 (4), p. 4-10, doi: 10.1130/GSATG70A.1

Pavlis, T.L., Langford, R., Hurtado, J., 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, doi: 10.1130/GES00503.1

De Paor, D.G., and S.J. Whitmeyer (2009) Innovations and redundancies in geoscience field courses: Past experiences and proposals for the future. in Whitmeyer, S.J., Mogk, D., and Pyle, E.J., eds., Field Geology Education: Historical Perspectives and Modern Approaches: Geological Society of America Special Paper 461, p. 45–56, doi: 10.1130/2009.2461(05)

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Point Cloud to 3D Print:

Now thoroughly veering off the topic of GeoPads but too cool not to share...graduate student Jozi Pearson put together an excellent resource walking through the procedures to go from point cloud data (lidar or SfM .las file) to a 3D print (.stl file) using free open-source softwares. To demonstrate this she took some of the 2005 B4 Project lidar point cloud data for Wallace Creek (world famous example of strike-slip fault offsets on the central San Andreas Fault) hosted by OpenTopography, added vertical exaggeration and cut the data along the fault to create a valuable teaching resource to demonstrate the interaction between faults and landscapes.   PDF   is   available   for   download   here: geopad.ucr.edu/Pointcloudto3DprintPearson.pdf

Crowdsourcing & Citizen Science:

USGS Citizen Science
https://www2.usgs.gov/blogs/features/usgs_top_story/citizen-science-for-citizens-science-and-the-planet/

British Geological Survey Citizen Science
http://www.bgs.ac.uk/citizenScience/home.html
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Known FieldMove Glitches:

These have been communicated to Midland Valley Feb 2017.

* linework frequently shifts location after drawing and becomes more "jagged" (not as mapped)
* sometimes specific units are not selectable in compass or drawing menu (seems to be related to the specific position in the list)
* GPS automatically turning off for no obvious reason (requires FM to be closed, reopened, then GPS checked back on)
* miscellaneous crashes, especially for data-rich projects
* in KMZ exports dotted lines become solid (perhaps this can't be fixed?)
* if you try to edit an exported KMZ in Google Earth (a line for example) it often crashes Google Earth

FieldMove Software Requests:

These have been communicated to Midland Valley Feb 2017.
* Add a "force compass calibration" option. This would be excellent!
* Currently only raster data import support through map layers. Possible to import vector data? Like from a KMZ? I'm sure this is a big ask...
* Importing data from another FieldMove project, for example from another iPad in field via AirDrop, would be amazing!
* Support for GPS location accuracy down to 1m or less
* Compatibility with BadElf GPS (capable of cheap GPS location to 1m accuracy)
* Compatibility with GaiaGPS (this program can very easily and efficiently download high resolution mbtile files of many topo and aerial imagery for offline use; if there was an easy way to import these layers into FieldMove projects it would greatly improve the workflow)
* Support for higher zoom levels (e.g. 22; important for detailed mapping such as lidar data)
* Ability to rename default project folder (not "project1"; makes it a little harder to find when exporting)
* Move camera shutter button to the side (students note it is in the way/awkward in present location)
* Black/dark unit colors should have white text in lists (currently are unreadable as black on black)
* Make it easier/more obvious to get back to map from "Help"
* Please add a "cleared to update" page to your website. This would essentially say whether it is safe to update to the latest iOS version Apple releases or if glitches have been identified (e.g. the frequently garbled text issue) and people should wait for a FieldMove update before updating iOS.