

# The Transition from Traditional to Digital Mapping: Maintaining Data Quality while Increasing Geologic Mapping Efficiency in Alaska

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## Introduction

The Alaska Division of Geological & Geophysical Surveys (DGGs) Mineral Resources section collects, analyzes, and publishes geological and geophysical information on Alaska's State- and Native-owned lands in order to inventory and manage Alaska's mineral resources. Knowledge of Alaska's mineral resources and framework geology is key to developing a strong mineral industry in the state, which in turn provides employment for Alaska's citizens and revenue to local governments. The Mineral Resources section typically maps and publishes at least one geologic map per year in an area of high mineral potential. In an effort to further streamline the methodology of producing these maps, the DGGs Mineral Resources section is investing in the potential for digital mapping in the field in order to create maps more efficiently. Other DGGs sections that conduct fieldwork and publish maps (Energy Resources, Volcanology, and Engineering Geology) may also adopt this technology as situations allow. DGGs anticipates that the move to digital mapping will take a number of years to fully implement and involve a few false starts. Here, we discuss the issues encountered so far and the choices made to further our objective—increased efficiency via digital mapping.

## What is Digital Mapping?

Digital mapping is defined as using a computer or personal digital assistant (PDA) to record and display information that has traditionally been recorded on paper, whether on note cards, in a notebook, or on a map. Geologic mapping is an interpretive process involving multiple types of data, running the gamut from analytical data to personal observation, all synthesized and recorded by one person. With field experience over time, geologists generally develop efficient, effective personal styles of mapping with which they are comfortable. This "traditional" geologic mapping can be accomplished by a geologist almost as well in inclement weather and when surrounded by mosquitoes as in ideal conditions.

Computer technology and software are now becoming portable and powerful enough to perform some of the more mundane tasks that a geologist must do in the field, such as precisely locating oneself, simultaneously viewing multiple maps, plotting structural data, symbolizing stratigraphic units or contact types, etc. Additionally, computers can now perform some tasks that were difficult to accomplish in the field, for example, digitally recording text or voice and annotating photographs. For digital mapping to become the standard operating procedure, geologists must use the computer in the field to become more efficient, retain their effectiveness as scientists, and create a new but comfortable, personal mapping style.

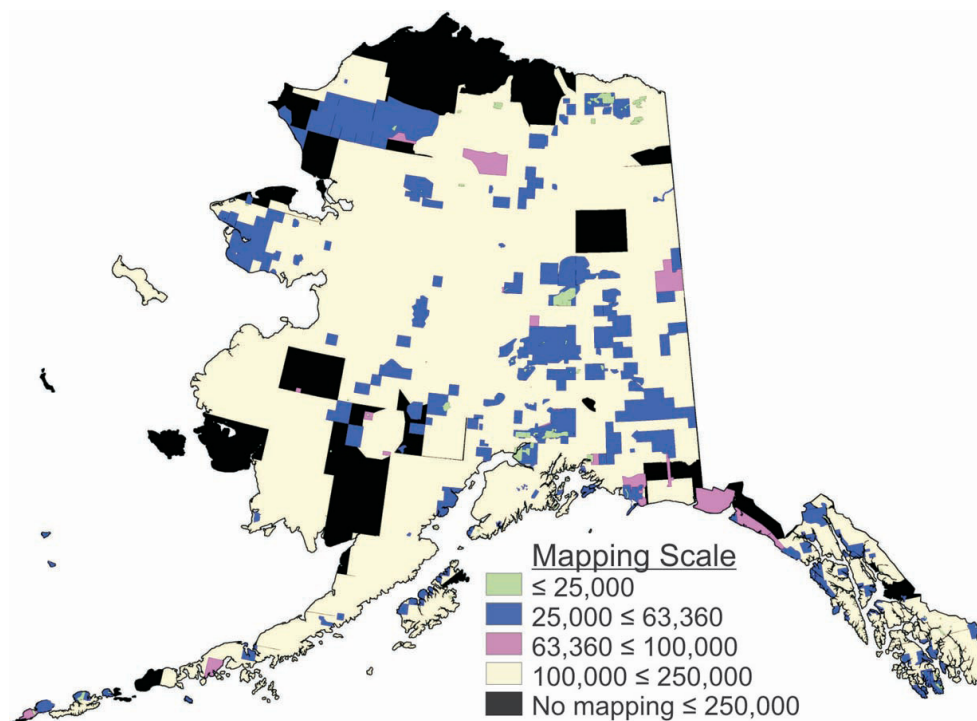
## Why Are We Considering Digital Mapping?

DGGS is constantly looking for ways to improve its geologic mapping workflow. In the end, given the normal, interrelated parameters of funding, available personnel, and time, we want to be as efficient as possible to produce the best possible product. We believe that digital mapping may get us closer to our goal. The main factor driving this effort is the 'time' parameter, in a number of ways.

As of 2006, geologic mapping had been completed for only about 16 percent of Alaska's 586,000-square-mile area at a scale larger than 1:250,000 (Figure 1). Due in part to the scale of available U.S. Geological Survey topographic maps as well as the coverage of existing geologic mapping, most new mapping in the lower 48 States is published at a scale on the order of 1:24,000, while new mapping in Alaska is generally published at scales of 1:50,000 or 1:63,360. At the current rate of mapping, DGGS estimates that it will take 250 years to cover the remaining State- and Native-owned bedrock areas of Alaska with 1:63,360-scale geologic maps. That daunting amount of work requires us to focus on areas with time-sensitive, high-impact value to the State, such as mineral and energy potential, hazards to citizens and infrastructure, and new transportation corridors.

Not only is there a lot of ground to cover, but a very short field season in which to map it. The optimal weather window in Alaska lasts 3 months: June, July, and August. Cold temperatures, snow cover, ice overflow in streams, and frozen ground severely hamper geologic fieldwork at other times of the year. The ever-rising cost of fieldwork also plays a large role in the amount of ground covered in a year. Since most of Alaska is inaccessible by road, helicopter transport is a necessary but expensive tool for fieldwork. Other large field expenses include helicopter fuel, fuel transport and storage, remote lodging, food and gear transportation, personnel travel, and rock sample shipments. To take advantage of the short field season and minimize field costs, DGGS typically deploys a group of five or six geologists to work in the field for up to 2 months at a time.

Timely release of data to the public, and prompt fulfillment of obligations to funding sources, are also very important. For example, the Federal STATEMAP program, one of our major funding sources for geologic fieldwork, has a turn-around time of 1 year for submitting products. With the current mapping methodology, DGGS is challenged to meet this deadline. We believe that the greatest benefit of digital mapping will be a decrease in the amount of project time necessary for data entry, potentially decreasing the overall time needed to complete a project.



**Figure 1.** Map of Alaska showing status of bedrock geologic mapping at various scales as of 2006. Note: A significant portion of the Aleutian Islands is not shown on this figure. About 42% of the Aleutian Islands' land not shown (approximately 2,500 square miles) is mapped at a scale of 1:63,360 or larger, and half of their area is mapped only at a regional scale (>1:250,000).

## Effects on the Geologic Mapping Process

DGGS Mineral Resources section first started looking at digital mapping in 2005 as a way to streamline the mapping process. Throughout the mapping process, digital mapping has positive and negative effects; only an assessment of its impact on the project as a whole will determine whether it is worthwhile. For simplicity, the mapping process is divided into fieldwork, data entry and basic data management, and data analysis. The current traditional methodology and digital mapping advantages and disadvantages are discussed below for each category. Particularly important advantages or disadvantages are *italicized*.

### Effects on Fieldwork

Currently, DGGS Mineral Resources section employs the team model to conduct fieldwork. A crew of five or six geologists works in the same general area and compares observations nightly. Geologic observations are recorded on rain-proof (<http://www.riteintherain.com/>) standardized note cards (Figure 2) and plasticized paper maps (<http://www.igage.com/WeatherP.htm>). GPS locations are recorded on paper and saved in the GPS device. Observations are

compiled by each crew member onto a single mylar basemap in the field office. No single geologist is responsible for the interpretation of an area; instead, geologic interpretations are stronger because the whole crew provides input. Project managers are responsible for arbitrating final interpretations. With the use of computers in the field, the recording of observations will change dramatically.

#### Advantages of Digital Mapping

- Computer screen automatically shows the location of the geologist.
- Feature data and attributes are entered directly into GIS. Features can be automatically color coded.
- Station (point) attribute data such as location, rock type, stratigraphic unit, textures, mineralogy, magnetic susceptibility, etc., are recorded directly by the geologist into a database. The geologist has total control of how the data are parsed into the database.
- Structural data are plotted automatically.
- Geologists can enter lengthy narrative descriptions into multiple data fields instead of the available free-text field, making the data more easily searchable and queryable.
- *Feature (point, line, and polygon) attributes are saved as digital text.*
- Geologists can upload each others' data files for the next day's fieldwork, for reference.
- Multiple maps and imagery (geophysics, ortho-photos, etc.) are easily carried and displayed on-screen.
- Geologists can take photographs and annotate them in the field. Photographs are immediately associated with a location.
- Hand-drawn stratigraphic sections, columns, outcrop interpretations, etc., are captured digitally. Drawings are immediately associated with a location.

#### Disadvantages of Digital Mapping

- Computers and related items (extra batteries, rain-proof cases, etc.) have to be carried in the field.
- Because computers are more fragile than water-proof paper, geologists have to take more care with them. (In most cases, short of a complete computer submersion in water, data can be recovered from the hard drive.)

NEF STATION# 072173 DATE 6/12/07 Quad CIR B5  
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LOCATION TYPE (circle) S/C FL Other  
COMMENTS B16, B16 etc! 25 ft fault \* 100 ft 100 ft

**SAMPLE** % O/C DESCRIPTION CIRCLE  
NS # A 90 100m - ? fold? Q<sub>1</sub> trite (X) TX MOX TE REE  
Blackish, angular, Fe-stained, broken, is it GX STN AGE OTHER  
gray color, granular texture, ~1/5 to yellow-orange spots + pits - vt Om c vc  
summer ca or bed? No rkn to HCL. ~100m. Features X-weathered dike  
has drusy qtz lining stained by Fe ox. (Ave = 0.08) MS 0.07, 0.04, 0.11, 0.07, 0.09  
NS # B 10 Ca-uvn-qtz schist (X) TX MOX TE REE  
Semi schist base to schistose qtz rich schist layers in A; GX STN AGE OTHER  
generally 10-15 cm thick. 25 to orange Fe-stained & w/le vt f m c vc  
rkn to HCL ca. dike  
Ave = 0.14 0.12, 0.14 MS 0.15, 0.09, 0.17, 0.13, 0.18  
NS # C tr Fe-stained v. (X) TX MOX TE REE  
white to orange, Fe-stained, occasional vuggy GX STN AGE OTHER  
qtz v. to fal. V. up to 5 cm wide. Vugs have drusy vt f m c vc  
qtz-stal linings, orange Fe-stained, orange-brown Fe-stained pseudomorphs dike  
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NS # \_\_\_\_\_ HS TX MOX TE REE  
GX STN AGE OTHER  
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dike  
MS

Bedding	Fault	Strike/Trend	Dip/Plunge	Thickness	Sample #
Fol	293	08			
Fol	298	09			
Fol	340	15			

Comments: good strike surface  
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Figure 2. Example of a completed field note card.

- Geologists must be trained, competent, and comfortable with the hardware, software, and database.
- *Data entry into the computer by the geologist takes longer than physically writing on paper, possibly resulting in longer field programs.*
- Narratives provide detailed descriptions that are not adequately captured by the information parsed into data fields.
- Geologists may be inclined to shorten narratives because they are more difficult to enter, resulting in loss of data.
- The tremendous amount of detail present in some hand-drawn stratigraphic sections, columns, and outcrop interpretations cannot be captured by tablet-stylus entry, resulting in loss of data.
- Geologists may have a more difficult time seeing the regional perspective on a 7-inch computer screen than on larger paper maps, because panning is required.

## Effects on Data Entry and Basic Data Management

DGGS Mineral Resources section currently hires student interns to perform data entry and basic data management for field projects. In the field office, the intern enters GPS data and field station data from standardized note cards into an Access database (Figure 3). The intern translates poor handwriting and abbreviations, interprets the geologic notes, and parses the data into a complicated set of database forms. It is not uncommon for data to be mistranslated or parsed into incorrect fields within the database, and these errors are difficult to identify.



**Figure 3.** Student intern Liping Jing downloads GPS data into the database.

In the past few years, interns have spent up to 7 months during and after the field season performing data entry. Since interpretation by the geologist must wait until data loading is completed, a long period of data entry can delay the whole project. This part of our current methodology would benefit the most from adoption of digital mapping methods.

### Advantages of Digital Mapping

- *Data entry by geologists only (no student intern) takes less total time, potentially reducing the overall time needed to complete a project.*
- Data entered by geologists have fewer errors.
- Interns have additional time during the day to work with field geologists.
- Post fieldwork, interns' time is better spent gaining experience and helping with sample preparation, data analysis, and GIS.

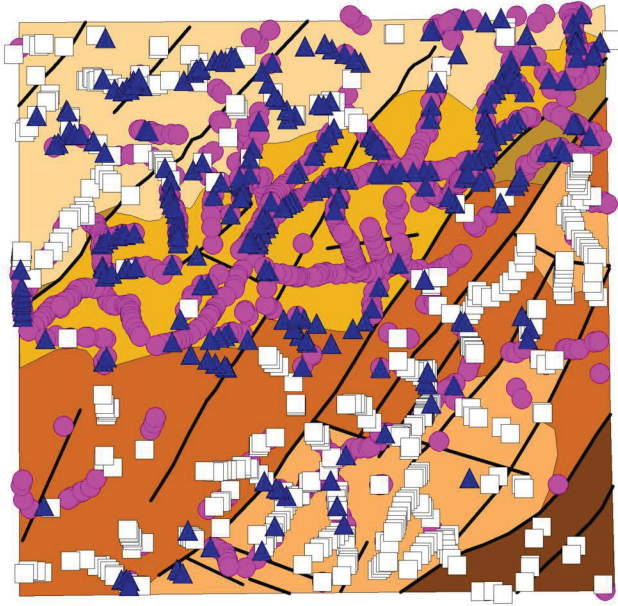
### Disadvantages of Digital Mapping

- Interns need additional training in database replication and synchronization.
- Nightly, databases need to be downloaded, synchronized, and uploaded onto field computers.
- Interns need training in GIS and operation of field computers.
- Nightly, GIS files need to be backed up from field computers, compiled, and re-uploaded.
- There are no original, hardcopy field maps or notes to archive. Paper is a more stable medium than digital format.

## Effects on Data Analysis

Geologic units in Alaska are typically defined at the scale of 1:250,000. The more detailed 1:63,360-scale mapping completed by DGGS tends to delineate new lithologies (rock units with specific physical characteristics) and change previous geologic interpretations. Defining new lithologies and creating a bedrock geologic map is an iterative process requiring the spatial analysis of field data, airborne magnetics and resistivity geophysical data, geochemistry, petrography (classification of rocks by microscopic examination), age data, and other information. Mineralogical and textural data and magnetic susceptibility are queried from the database to help differentiate lithologic units (Figure 4). Digital mapping would affect when data analysis could occur, but not greatly affect the process itself.





**Figure 4.** Data queried from the field database can be useful in differentiating lithologies. In this example, metamorphic units can largely be recognized by their relative abundance of garnet (pink circles), relict sandstone grains (white squares), and carbonate (blue triangles). Map area is about 14 by 14 miles.

#### Advantages of Digital Mapping

- Analysis of field data can start immediately after returning from the field, since the database has already been populated.
- GIS data input in the field can be directly added to the digital working copy of the map.

#### Disadvantage of Digital Mapping

- Data entered by multiple geologists contain more inconsistencies than data entered by one person, making the database more difficult to query.

## Digital Mapping Equipment

In practice, digital geologic mappers are expensive and difficult to outfit. The initial cost of computing and supporting equipment may be significant. In addition, equipment and software must be replaced occasionally due to damage, loss, and obsolescence. Hardware and software only recently (in 2007 and 2008) became available that can satisfy most of the criteria DGGs identified in 2005 as necessary for digital mapping (Table 1). Products moving through the market are quickly discontinued as technology and consumer interests evolve. A product that works well for digital mapping may not

be available for purchase the following year; however, testing multiple brands and generations of equipment and software is prohibitively expensive.

DGGs is currently field testing Samsung's Q1P SSD and Q1U-SSDXP tablet computers (<http://www.samsung.com/>), the 12-channel DeLorme Earthmate BT-20 GPS (<http://www.delorme.com/>), and the Kodak Easyshare V610 camera (<http://www.kodak.com/>; discontinued product). (Note: Models listed are not necessarily all-inclusive of those potentially capable of meeting requirements for field entry of geologic data. Brand names are examples only and do not imply endorsement by the State of Alaska.) The full list of gear includes the computer, two 6-cell computer batteries, stylus, computer case, sealable plastic bags, screen protector, shoulder strap, GPS with extra battery, camera, mini tripod, and other camera accessories (Figure 5). The Q1P SSD units and all supporting equipment cost \$2,707 in 2007 and weigh 3.9 lb. The Q1U-SSDXP units and all supporting equipment cost \$2,032 in 2008 and weigh 4.2 lb.

Software being tested includes ESRI's ArcPad 7.1.1 (<http://www.esri.com/>), Geologic Data Assistant (GDA) extension for ArcPad (Thoms and Haugerud, 2006; <http://pubs.usgs.gov/of/2006/1097/>), Microsoft's Access and OneNote (<http://office.microsoft.com/en-us/onenote/>), and EverNote's RitePen (<http://www.ritescript.com/>). ArcPad and GDA are GIS software that work together with a GPS in real time to show the geologist's current location or to digitize new features on-screen. GDA, an ArcPad extension created for geologic mapping, has been upgraded (with minor software bugs) from ArcPad 6.0.3 to version 7.1.1. DGGs is testing OneNote as a container for photographs, annotation, sketches, and narratives, and for its text recognition capability. Access houses the field database and is being tested as a field application.



**Figure 5.** Q1P SSD tablet and supporting digital mapping equipment.

**Table 1.** DGGS's digital mapping requirements for hardware and software. *Italics indicate features not currently present in the Samsung's Q1 series tested by DGGS. Some features may be added or configured through extra hardware or software.*

Essential features	Desirable features
<ul style="list-style-type: none"> <li>• Intuitive to learn and easy to use.</li> <li>• Screen about 5" x 7"—compact but large enough to see map features.</li> <li>• Lightweight—must be less than 3 lb.</li> <li>• <i>Rugged</i></li> <li>• <i>Waterproof</i></li> <li>• Transcription to digital text from handwriting and voice recognition.</li> <li>• Can store paragraphs of data (text fields).</li> <li>• Can store complex databases with dropdown lists.</li> <li>• <i>Screen is easy to read in bright sunlight and on gray sky days</i> (could be configured).</li> <li>• Removable static memory cards can be used to backup data.</li> <li>• Chargeable by unconventional power sources (generators, solar, etc.).</li> <li>• Wireless real-time link to GPS.</li> <li>• Can change batteries in the field.</li> <li>• Operating system and hardware are compatible with robust GIS program.</li> </ul>	<ul style="list-style-type: none"> <li>• USB port(s)</li> <li>• <i>Case to protect from rock samples</i> (can be purchased separately for Q1U-SSDXP).</li> <li>• At least 512 MB memory.</li> <li>• Memory on board is recoverable.</li> <li>• Batteries should have no "memory," such as with lithium ion.</li> <li>• Wireless real-time link to computer, camera, and other peripherals.</li> <li>• <i>Portable battery with at least 9 hours of life at near constant use.</i></li> <li>• <i>Real-time and post-processing differential correction for GPS locations</i> (could be configured).</li> </ul>

RitePen is a "write anywhere" handwriting recognition program that allows text entry in Access forms, as well as in many other programs.

## Digital Mapping Computer

Two hardware requirements stood out as particularly important for the digital mapping computer—screen size and weight. Weight, in particular, is of serious concern. At the end of a field day, DGGS minerals geologists already regularly carry 80 pounds of gear and rocks. From the computers and PDAs available in 2007, Samsung's Q1P SSD met the most requirements for our first attempt at digital mapping. Rejected options included PDAs because of their small screen size and lack of computing power, and rugged laptops and rugged tablets because of their heavier weight.

The Samsung Q1P SSD is a small but powerful tablet PC that runs Windows XP Tablet PC Edition. Its predecessor, Samsung's Q1, was one of the first Ultra-Mobile PCs (UMPC) launched in 2006 in response to Microsoft's Origami Project, which was a challenge to manufacturers to make a small, touch-screen computer, optimized for mobility (Note: Origami project closed; URL: <http://origamiproject.com> no longer operative]). Since then, Samsung has offered several redesigned iterations of the computer, two of which are the Q1P SSD (discontinued product), and the Q1U-SSDXP (or Q1 Ultra SSDXP). DGGS is currently field testing two each of these computers. Both of the UMPCs feature a 32 GB solid state (NAND flash memory) hard drive. Hence, the computer does not have a spinning hard drive, is more resistant to damage from accidental drops, and creates less heat when

operating. Additionally, battery life is significantly increased because a motor is not required to constantly spin the hard drive. Both computers also have a 7-inch screen and weigh less than 2 lb with the extended 6-cell battery. See Table 2 for their specifications.

For a field computer, the biggest drawbacks of the Q1 series for DGGS purposes are their limited ruggedness and lack of waterproofing. Custom carrying cases were locally manufactured by Apocalypse Design, Inc. (<http://www.akgear.com/>) for the Q1P SSD tablets that add some protection from drops and contact with rocks. The case has a plastic shield to protect the tablet's writing surface, mesh fabric that allows air circulation, and several tabs to attach carrying straps. The Q1U-SSDXP tablets have carrying cases manufactured by OtterBox (<http://www.otterbox.com/pc-tablet-umpc-cases/samsung-q1ulup-case/>). The OtterBox 1990 Defender Case for Q1 Ultra UMPCs has a thermal-formed protective clear membrane to protect the writing surface, a high-impact polycarbonate shell, and a silicone layer that covers the unit and its ports. Both cases provide some water resistance but do not make the tablets waterproof.

Although inherently problematic, sealable plastic bags were determined to be the tablets' best protection against water intrusion. Concern about overheating problems due to lack of air flow in the plastic bags led to a series of heat tests. A Q1P SSD tablet was set up with a program that measures ambient air temperature, graphics processing unit (GPU) temperature, memory temperature, and CPU die-core temperature. To ensure that the computer generated the most heat possible, a process was activated that writes to and then erases 80 percent of the available memory while drawing random polygons on

**Table 2.** Selected specifications for the Q1P SSD and Q1U-SSDXP from <http://www.samsung.com/>.

Feature	Q1P SSD	Q1U-SSDXP
Operating system	Windows XP Tablet Edition	Windows XP Tablet Edition
Processor	Intel Pentium M ULV, 1.0 GHz	Intel Ultra Mobile Processor A110, 800 MHz
Storage	32GB SSD	32GB SSD
Memory	1GB DDRII 533	1 GB DDRII 400
Graphics	Intel® Graphics Media Accelerator 900, 128 MB	Intel® Graphics Media Accelerator 950, 128 MB
Display	7" WVGA Touch Screen LCD, 800 x 480, 280 nits	7" WSVGA Touch Screen LCD, 1024 x 600, 300 nits
Communications	802.11b/g Wi-Fi, 10/100 Base-TX Ethernet, Bluetooth 2.0	802.11 b/g Wi-Fi, 10/100 Base-TX Ethernet, Bluetooth 2.0 + EDR
Ports	Two USB 2.0, One Type II CF card, Headphone Jack, VGA	Two USB 2.0, 2-in-1 Memory Slot (SD/MMC), Headphone Jack, VGA
Dimension	9.0 x 5.5 x 1.0 inches	8.96 x 4.88 x 0.93 inches
Weight with battery	1.7 lb (with 3-cell battery)	1.4 lb (with 4-cell battery)
Keyboard	N/A	QWERTY Key Pad
Camera(s)	N/A	Front Facing Video 300 P, Rear Facing Video/Still 1.3 MP

the screen, and that uses leftover CPU cycles to compute the square root of a random 25 digit number.

The computer was placed in a sealed plastic bag, and its temperatures were monitored over the life of the standard 3-cell battery while the computer was located at room temperature and then in a 150°F oven. Then the computer was turned off, placed in its sealed bag, and chilled overnight in a -25 °F freezer. In the morning, the heat-generating processes were restarted. The computer was placed back in a sealed plastic bag and again in the oven at 150°F until the battery ran down. While the CPU did in fact slow down during these tests, it never faltered, never shut down, and never melted. The computer's self-preservation mechanism (based on temperature) slowed the processor down to slower and slower speeds in order to consume less power, thereby creating less heat.

## 2007 Field Test

During the summer 2007 field season, two geologists using Q1P SSD tablets tested the digital mapping equipment for 1 day. Hardware and setup issues included poor screen visibility in bright sunlight (Figure 6) and Bluetooth connection problems with the camera. It was feasible but inconvenient to cover the computer with two layers of plastic (case and sealed plastic bag) while trying to operate the buttons, and the plastic layers made screen-viewing more difficult.

In a similar field situation with Samsung Q1P series computers, Alaska Division of Forestry (DOF) field personnel had difficulty maintaining consistent Bluetooth GPS connections. DOF prefers built-in GPSs. Their temporary solution is to use external plug-in CF GPS receivers; however, field personnel

have broken off two external antennas during normal use. DOF solved the screen visibility problem by replacing their computers' screens (3 Q1P and 2 rugged laptops) with Advanced Link Photonics, Inc. (<http://www.alpincorp.com/>) resistive touch transfective LCD screens (Thomas Kurkowski, oral commun., 2008). The enhanced resistive touch screens reduce glare from 10 to 20 percent on regular screens to 1 percent reflected light, and the LCD screens are transfectively



**Figure 6.** Surficial geologists Dick Reger (bottom left) and Trent Hubbard (under tarp) attempt to minimize screen glare and protect unit from rain while working.



upgraded and often brighter with an increase in nits by 10–30 percent (Advanced Link Photonics, Inc., oral commun., 2008).

Software issues included annoying virus software popup messages, problems recording lengthy text and with text recognition in Microsoft OneNote, and GDA incompatibility with DGGS-style field notes. In general, more time needs to be spent setting up an easy-on, automatically configured interface for field geologists so there are no or minimal technical details to manage in the field. To truly have a seamless field data entry system requires a customized, form-based, GIS-database interface.

## 2008 Field Test

Several personnel from DGGS Mineral Resources and Engineering Geology sections are currently testing the Q1P SSD and Q1U-SSDXP field computers. In 2008, the Access field database was replicated and placed on the tablets for direct data entry. RitePen text recognition software was provided for data entry into the Access form. Staff set up ArcPad with project GIS files to automatically load with the program, and configured GPSs with Bluetooth to provide location information to ArcPad and GDA. A Bluetooth camera was also configured to add pictures to Microsoft OneNote, where they will be annotated.

Initial impressions are that the digital mapping hardware and software were better configured this year than in 2007 but that the geologists were not adequately prepared to use the equipment. Most geologists were not familiar enough with the tablet computers, Access database, new GPSs, and how the text recognition software worked to complete meaningful field data entry. Geologists were also fearful that they would damage the hardware and were reluctant to carry it, especially in inclement weather. Thus far, positive feedback includes good performance by the RitePen text recognition software, seamless GPS connectivity via Bluetooth, good performance by the system overall as a navigational aid in the helicopter, successful capture of geologic contacts and attribute data (Figure 7), and potential use of the computer as a pocket handwarmer.



**Figure 7.** Geologist Trent Hubbard successfully records geologic data digitally.

## Future of Digital Mapping at DGGS

Before the next field season, interested DGGS geologists will spend more time learning to use the computers and software so that they are comfortable enough with them to collect at least several days' worth of data in the field. For 2009, there will probably only be minor changes to the configuration of the computers. New daylight readable screens may be the biggest potential improvement in the system.

In the long term, some significant software changes are necessary to truly make digital mapping viable. The biggest hurdle will be creating a simple, user-friendly, form-based interface in ArcPad that can capture GIS features as well as detailed geologic data at field stations. Before that can happen, however, the Access database will need to be migrated to ESRI ArcMap (<http://www.esri.com/>), and then served out to ArcPad.

In conjunction with the move, the field database will probably be redesigned to more closely match the structure of DGGS's enterprise Oracle database (Freeman and others, 2002; Freeman and Sturmman, 2004). The redesign, development of data loading routines, and decisions about data flow and editing could start in mid-2009. To date, only station and sample field data from recent projects have been entered into the enterprise database. DGGS has had little time and no dedicated funding to perform this task. With the field database redesign, we hope that after the data have been quality controlled, it will be a fairly simple matter to load all of the data into the Oracle database.

The next step, creation of the data entry form using ESRI's ArcPad and ArcPad Application Builder (<http://www.esri.com/>), could begin in 2010. Design of the form will also require Visual Basic Scripting, possibly developed with the help of an outside contract. The interface will be designed for geologists' ease of use and could be field tested as early as 2011.

## Conclusions

DGGS Mineral Resources section recognizes that the current methodology of geologic mapping can be more efficient, especially in the way field data are recorded. DGGS minerals geologists currently write field station and sample observations on note cards, which are later entered into an Access database by a student intern. In the past, data entry by student interns has taken up to 7 months. Given the limited amount of time available to complete mapping projects, this excessive period of data entry is unacceptable.

DGGS is considering digital mapping as a way to streamline the mapping process. To that end, we are evaluating the effectiveness of having geologists enter geologic observations directly into an Access database and GIS software on Samsung ultra-mobile tablet computers. Brief field tests in 2007 and 2008 suggest that the equipment and software have



the potential to work as a digital mapping system but that significant work is still needed to create a system that will facilitate comfortable data entry by field geologists.

We will continue to work on new solutions and keep an eye out for new technology that will help alleviate some of the problems discovered thus far, including limited ruggedness and lack of waterproofing of the units. In the next couple of years, DGGS will train additional geologists on the computers and software so that we can then conduct more comprehensive field tests. Plans include migration of the field database to ESRI's ArcMap and ArcPad, and creating a user-friendly GIS-database data-entry interface. Through sharing ideas and results, we anticipate that it will be possible to create a DGGS-wide digital mapping system capable of benefiting all of the field projects. If the process proves effective, we anticipate that within a few years most DGGS geologists will be out on the outcrop with small field computers, happily, but more efficiently, creating geologic maps, reports, and digital data to better serve the public's needs for resource evaluation, hazards identification, and well informed land-use management.

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