Preservation, Digital Conversion and Accessibility of the Minnesota Geological Survey Downhole Geophysical Database

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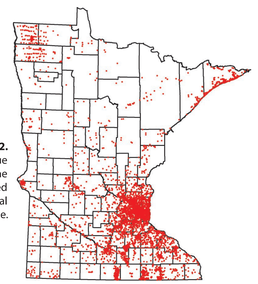
1. ABSTRACT

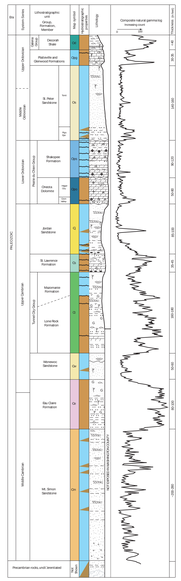
The Minnesota Geological Survey houses approximately 7650 downhole geophysical logs collected from nearly 6300 boreholes over the past 35 years. Geophysical logs are imperative for mapping the subsurface where outcrops are scarce, and are commonly used to interpret water-bearing properties in our aquifer systems. The majority of logs contain gamma-ray data, and a small percentage also include measurements of electrical resistivity, spontaneous potential, water flow, temperature, and conductivity within open-hole intervals. Work is underway to create and update the digital infrastructure of these logs, focused currently on gamma-ray data, for preservation and accessibility, using funds awarded from the National Geological and Geophysical Data Preservation Program (NGGDPP). Data from about 5050 logs are being converted from proprietary Century Geophysical Corporation format into Log ASCII Standard (LAS) format, as well as converted to PDF documents for efficient dissemination. Nearly 2600 logs previously existed only on paper and have now been scanned to PDF images before these logs become further damaged or lost. A select number of these scanned logs deemed most important based on areas of low data density, deep drill holes and active mapping projects will be digitized using the automated digitizing software available in NeuraLog (www.neuralog.com). This process extracts x, y, and z data from static log images, allowing conversion to digital data in the LAS file format. An inventory database with metadata, at present not readily available to the public, exists for the entire collection and will continually be updated and checked for accuracy throughout the remainder of the project. Future work will involve setting up access for the public to query and obtain the metadata, PDFs, and LAS files online, and to eventually integrate the digital log database with the more widely used County Well Index (CWI) water-wells database housed at the Minnesota Department of Health to further streamline our mapping procedures. Our end goal is to increase the ease and use of our downhole geophysical database both for our staff and for the public, and to encourage collaborative work within the geoscience community by sharing our wealth of georeferenced geophysical data.

2. BACKGROUND

- Gamma ray logs have long been used to measure naturally occurring radioactive materials to help derive lithologies and make stratigraphic correlations on a local and regional scale.
- In the state of Minnesota, collection of downhole geophysical logs from new and existing water wells is imperative for mapping the subsurface geology where outcrops are scarce, particularly the sandstone, shale and carbonate units of Paleozoic-age, and are commonly used to interpret water-bearing properties in our aquifer systems (Figure 1).
- Geophysical data can also help provide a basic understanding of the underlying stratigraphy and casing record for older water wells that are no longer in use and that lack proper records describing materials encountered and well construction.
- The Minnesota Geological Survey has been actively collecting gamma ray data, often along with electrical resistivity, spontaneous potential, water flow, temperature, and conductivity data, for the last 35 years.
- Gamma ray logs are acquired using a downhole natural gamma logging tool in conjunction with Century Compu-Log acquisition and presentation software, both of which were purchased through Century Geophysical, LLC based in Tulsa, OK.
- Currently our records include nearly 7650 downhole geophysical logs, with nearly 2600 logs existing only on paper (Figure 2).



»FIGURE 2. Distribution of unique geophysical logs throughout the state of Minnesota contained within the Minnesota Geological Survey's database.

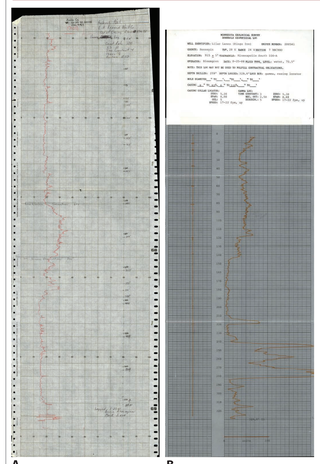


»FIGURE 1. A gamma log curve as it correlates to the stratigraphy and hydrostratigraphic properties of the Paleozoic bedrock in Washington County, MN. The gamma log is a compilation of the following borehole geophysical logs on file at the Minnesota Geological Survey: County Well Index unique numbers 783609, 777305, and 256005.

3. NGGDPP GRANT AND GOALS

- The National Geological and Geophysical Data Preservation Program (NGGDPP), administered by the U.S. Geological Survey, comprises State geological surveys and Department of Interior agencies working to: inventory and preserve materials and data; populate and advance the National Digital Catalog; and establish standards, procedures, and protocols for preserving and archiving collections.
- Starting in July of 2015, the MGS was awarded funds through the NGGDPP to preserve, digitize and update our downhole geophysical data collection over a 1-year timeframe.
- Our project goals include:
  - » Increasing the ease and usage of the MGS geophysical log collection, both for our staff and for the public
  - » Scanning the 2600 paper logs to PDF images for preservation, digitization and accessibility purposes
  - » Digitizing a select number of scanned PDF logs to recreate original quantitative data in the Log ASCII Standard (LAS) file format
  - » Converting about 5050 digital logs from a proprietary Century Geophysical format into standardized LAS and PDF file formats
  - » Updating and maintaining our existing downhole inventory database and metadata

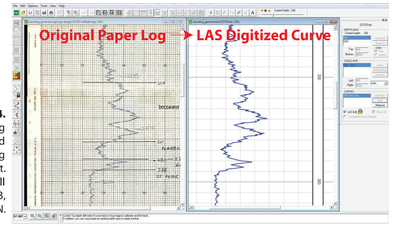
4. PRESERVATION: SCANNING AND DIGITIZING



A. B.

»FIGURE 3. Two examples of scanned gamma ray logs of varying quality using a continuous roll-feed scanner. (A) County Well Index unique number 171011, Anoka County, MN; (B) County Well Index unique number 200541, Hennepin County, MN.

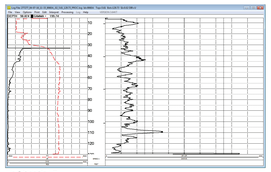
- About 2600 paper logs of varying size and quality were sent to students and staff at the University of Minnesota Elmer L. Andersen Library for scanning.
- Paper logs were scanned using a continuous roll-feed scanner and saved as PDF images (Figure 3). Care was taken to ensure safe-handling of fragile logs, and to produce properly-aligned and high-quality images.
- Through the use of NeuraLog (neuralog.com), an automated well log digitizing software, a select number of scanned paper logs are currently being digitized based on areas of low data density, deep drill holes and active mapping projects.
- NeuraLog enables us to re-capture the quantitative x, y data of the scanned paper images to produce usable LAS files and vectorized PDF images useful when creating scientific illustrations and gamma ray correlation diagrams (Figure 3).
- The procedure for NeuraLog includes:
  - » Importing a scanned geophysical image
  - » Entering corresponding metadata (i.e., well unique number, location, date logged, depth logged, etc.)
  - » Defining the measured gamma (x-axis) and depth (y-axis) axes of the scanned image and their units of measurement
  - » Using a series of built-in tools to automatically capture the gamma ray curve as a vectorized line, or creating this line manually when low data quality impedes the use of automatic recognition tools



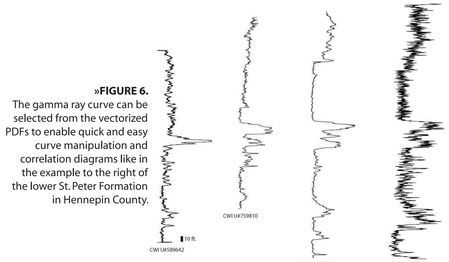
»FIGURE 4. Scanned paper gamma log (left) and resultant digitized LAS curve (right) after using the NeuraLog toolset. Example log: County Well Index unique number 227333, Dodge County, MN.

5. FILE CONVERSION: STANDARDIZATION AND ACCESSIBILITY

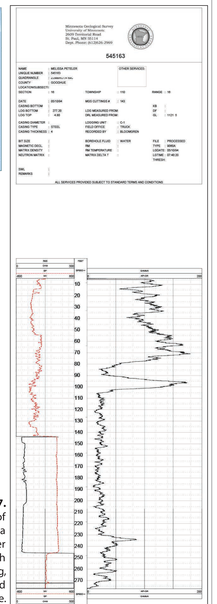
- An additional 5050 geophysical logs already exist in a digital format; however, these logs are in a Century Geophysical proprietary format and can only be viewed, manipulated, and/or printed using Century software (Figure 5).
- This program supports LAS file formats, but does not allow exporting to a PDF image.
- We developed a workaround procedure using a combination of free software, PDF Architect 3 (pdfforge.org) and PDFill PDF Tools (pdfill.com), in order to print Century-format logs into PDF images.
- This procedure results in one continuous (devoid of page breaks) and vectorized PDF image of each log (Figure 6). This makes visualizing and interpreting the logs easier for the end-user, while also enabling users to easily manipulate the gamma curves for scientific/illustrative purposes (Figure 7).



»FIGURE 5. Screen capture of an example gamma, electrical resistivity, and spontaneous potential log as viewed in Century Geophysical's Compu-Log software. Example log: County Well Index unique number 277277, Isanti County, MN.



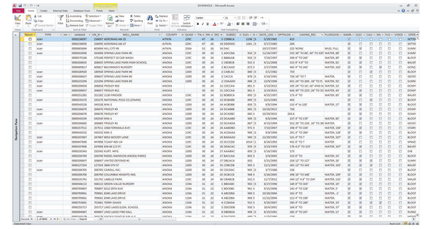
»FIGURE 6. The gamma ray curve can be selected from the vectorized PDFs to enable quick and easy curve manipulation and correlation diagrams like in the example to the right of the lower St. Peter Formation in Hennepin County.



»FIGURE 7. An example of one of our vectorized gamma log PDFs after processing through Century's Compu-Log, PDF Architect, and PDFill software.

6. DATABASE AND METADATA

- The MGS has maintained a Microsoft Access database for every downhole geophysical log within our collections, whether it exists digitally or only in paper format (Figure 8).
- Our robust database includes the following attributes:
  - » Unique number
  - » Well name
  - » Geographic location (county, quadrangle, township, range, section, subsection, UTM coordinates)
  - » Ground elevation
  - » Date logged
  - » Depth logged
  - » Casing record
  - » Borehole surface water level
  - » Type of log (gamma, electrical resistivity & spontaneous potential, caliper, multitool, flowmeter, video)
  - » Operator
  - » First stratigraphic unit (as interpreted)
  - » Last stratigraphic unit (as interpreted)
  - » Corresponding drill cuttings set (if any)
  - » Rationale for acquiring data
  - » Entry date
  - » Interpreted stratigraphy and corresponding depth intervals
- Steps are currently being taken to verify that all geophysical logs are accounted for within the database, and that our records specify if the log has been scanned, converted to LAS/PDF file formats, and/or digitized using NeuraLog.
- Currently all digital files exists on MGS internal servers. We have yet to directly link digital files to the Access database.



»FIGURE 8. Screen capture showing the current state of the MGS Downhole Geophysical Database in Microsoft Access. Continued work will add to this dataset, with the end-goal of making it more easily available to the public.

7. CONCLUSIONS AND FUTURE GOALS

- Preserving and managing nearly 7650 downhole geophysical logs is no easy task, but one of great importance given the daily use and value of the geologic information contained within.
- Geophysical data are used extensively in the production of our surficial and bedrock geology maps, and our continued research to better define the hydrostratigraphic properties of the bedrock. Our maps are then used by mineral-resource, water-resource, environmental, and public health professionals to understand local and regional geologic framework and make better decisions on how to use, manage, and protect our state resources.
- We highly recommend that other State surveys and agencies take advantage of the National Geological and Geophysical Data Preservation Program grant for similar projects, and to ensure the preservation of fragile, yet important, geologic and geophysical data.
- We also recommend using the NeuraLog software if looking to obtain quantitative digital log data and usable standard file formats from flattened scanned images. While the effectiveness of the automation tools vary upon image quality and contrast, each curve can still be digitized manually and obtain the needed end-result. We have yet to fully explore and take advantage of all of the tools available in NeuraLog.
- Our end goal within this 1-year grant period is to have every paper log scanned (already completed), every existing digital log converted to LAS and PDF file formats (ongoing), several important paper logs fully digitized and in LAS format (ongoing), and a fully up-to-date Access database (ongoing).
- Future goals include:
  - » Linking the direct file location of digital data to our Access database
  - » Integrating our Access database with the more widely used County Well Index (CWI) water-wells database housed at the Minnesota Department of Health to further streamline our mapping procedures.
  - » Making the database GIS-ready and easily accessible in-house for use by MGS staff to easily open and review existing digital geophysical data at individual workstations
  - » Making the database publically available on our website, possibly through ArcGIS Online, to share this wealth of data and promote collaborations and independent research
- We highly encourage communication, data transparency, and collaborative efforts amongst the scientific community, whenever possible.

ACKNOWLEDGMENTS

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