VIRGINIA'S CONTRIBUTIONS TO THE NATIONAL GEOTHERMAL DATA SYSTEM

NGDS National Geothermal Data System

Virginia Department of Mines Minerals and Energy

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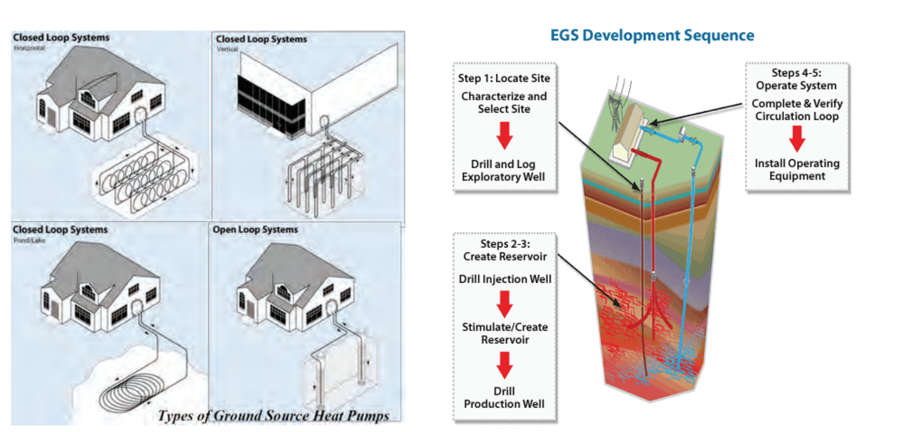
GEOTHERMAL ENERGY is the heat contained within the earth – a clean, reliable, and renewable energy. The heat energy is contained in normal occurrences of subsurface groundwater, which is transported to the surface of the earth by pumping. It can be used as an energy-efficient heating and cooling alternative for residential, commercial, and industrial applications, and is potentially a significant resource for electrical power generation in some regions of the United States.

Geothermal resources previously studied in the Appalachian Mountain System and the Atlantic Coastal Plain have been grouped into four types:

I. Water-saturated sediments of low thermal conductivity overlying radioactive heat-producing granites
II. Areas of normal geothermal gradient
III. Hot and warm springs emanating from fault-fracture zones as a result of leakage from greater depths
IV. Hot dry rock, especially radioactive granites beneath sediments of low thermal conductivity (Costain, et al., 1982)

Principal means of geothermal energy production in the eastern United States have been found to be low- to moderate-temperature fluids that are best suited for:

- Heat Pump (loop) Technology - low-temperature, highly efficient ground-source heat that can be extracted to cool homes in the summer and heat them in the winter
- Direct use of low- to moderate-temperature water (68°F to 302°F) for homes, industry and commercial uses
- Enhanced Geothermal Systems – deep engineered reservoirs requiring the addition of water, potentially nationwide at depths of 19,000 to 25,000 feet (6 to 8km)

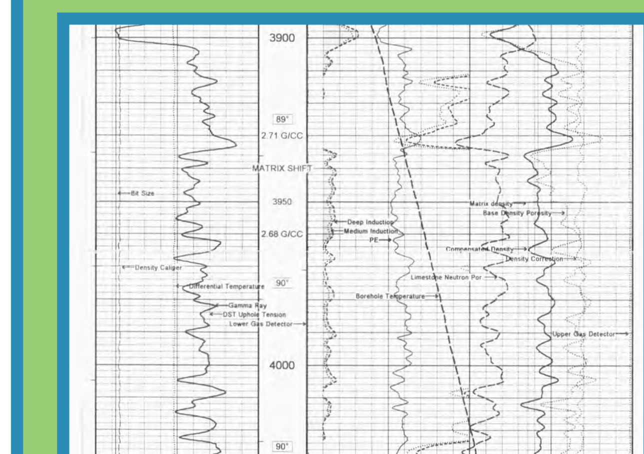


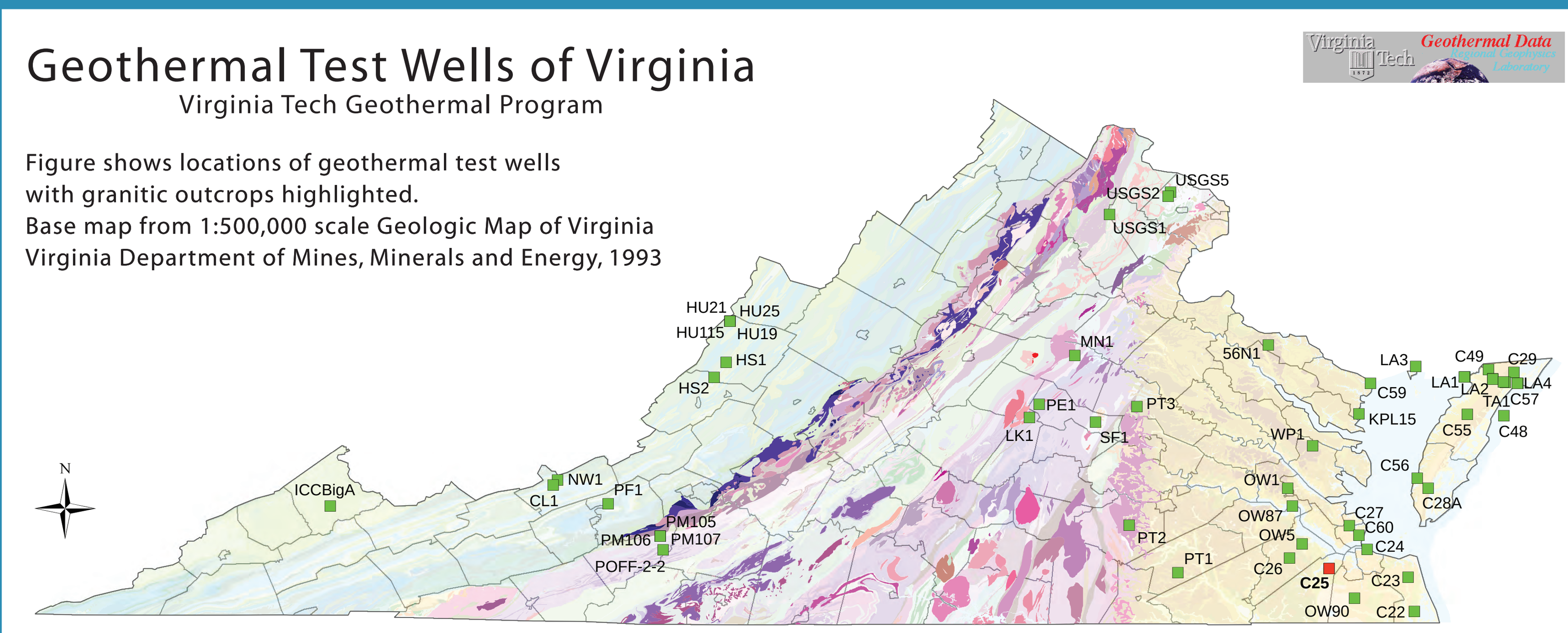
STATE GEOTHERMAL DATA

The Virginia Division of Geology and Mineral Resources (DGMR) participates in the National Geothermal Data System (NGDS), a U.S. Department of Energy-funded distributed network of databases for the acquisition, management and maintenance of geothermal and related data. Through a DOE grant that is administered by the Arizona Geological Survey (AZGS), Virginia along with other state geological surveys contributes data in the form of ***metadata*** to the NGDS. The objective of this ***3-year project*** is to populate, expand and enhance the NGDS by creating a national sustainable, distributed, interoperable network of predominantly state geological survey-based data providers that will develop, collect, serve and maintain geothermal relevant data that operates as an integral compliant component of NGDS. The DGMR Geothermal Program will contribute to the NGDS by gathering relevant data from **Virginia** and the nearby states of **Maryland**, **Delaware**, and **Georgia**.

The broad and diverse suite of data needed for effective exploration and development of geothermal energy resources are largely in analog form and must be digitized and tagged with metadata before submittal to NGDS. Listed below is a summary of data that will be submitted to the NGDS:

- **Borehole Lithology Logs** – descriptions of well cuttings and/or core from water, oil and gas, and geothermal wells
- **Hot Springs** – descriptions, flow data, water temperature and water chemistry when available
- **Geophysical Well Logs** – from water, oil and gas, and geothermal wells, including calculated temperature gradients
- **Bottom-hole Temperatures** – from geophysical logs from water, oil and gas, and geothermal wells
- **Temperature Depth Logs** – from geothermal test wells
- **Heat Flow Measurements** – from geothermal test wells
- **Thermal Conductivity Measurements** – from borehole samples from geothermal test wells
- **Existing Digital Databases** – Water Well Record Archives, Oil and Gas Well Database, Virginia Geologic Information Catalog
- **Geologic Maps** – detailed 1:24,000 scale, made available online as scanned images or in digtial format
- **Geologic Unit Descriptions** – including geothermal characterization from thermal conductivity measurements
- **Online Publications** – relevant references and citations





Geothermal Test Wells of Virginia

Virginia Tech Geothermal Program

Figure shows locations of geothermal test wells with granitic outcrops highlighted.
Base map from 1:500,000 scale Geologic Map of Virginia
Virginia Department of Mines, Minerals and Energy, 1993

Thermal Springs of Virginia

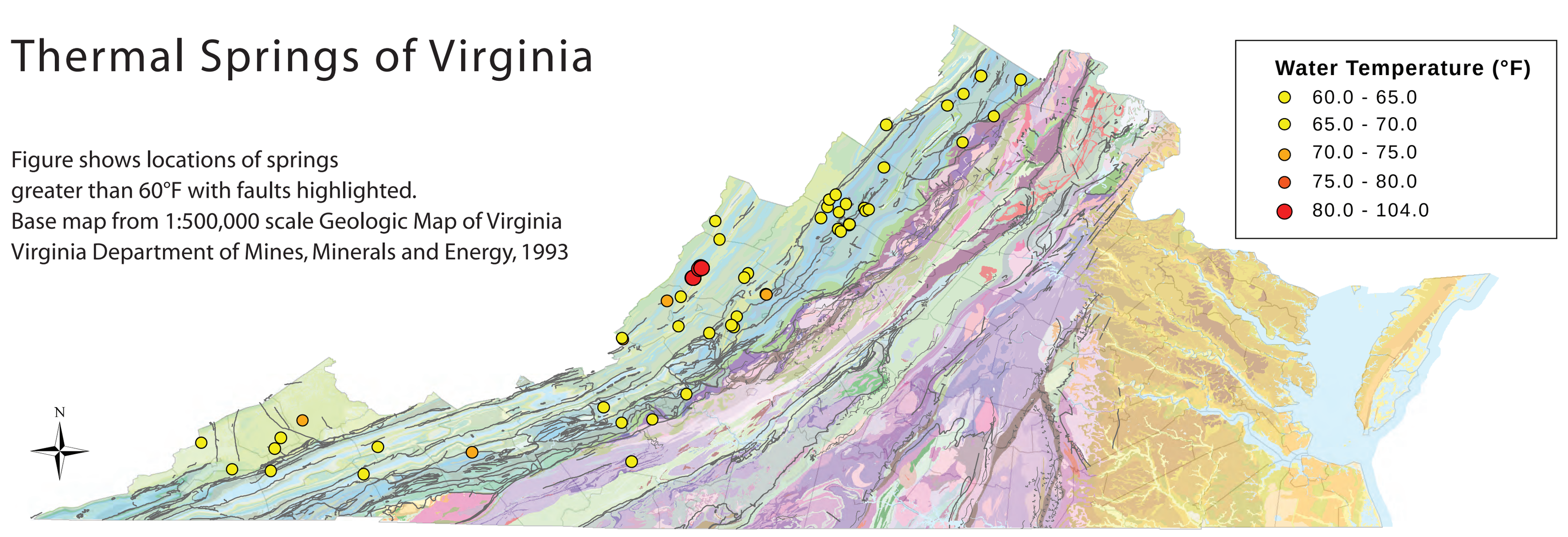
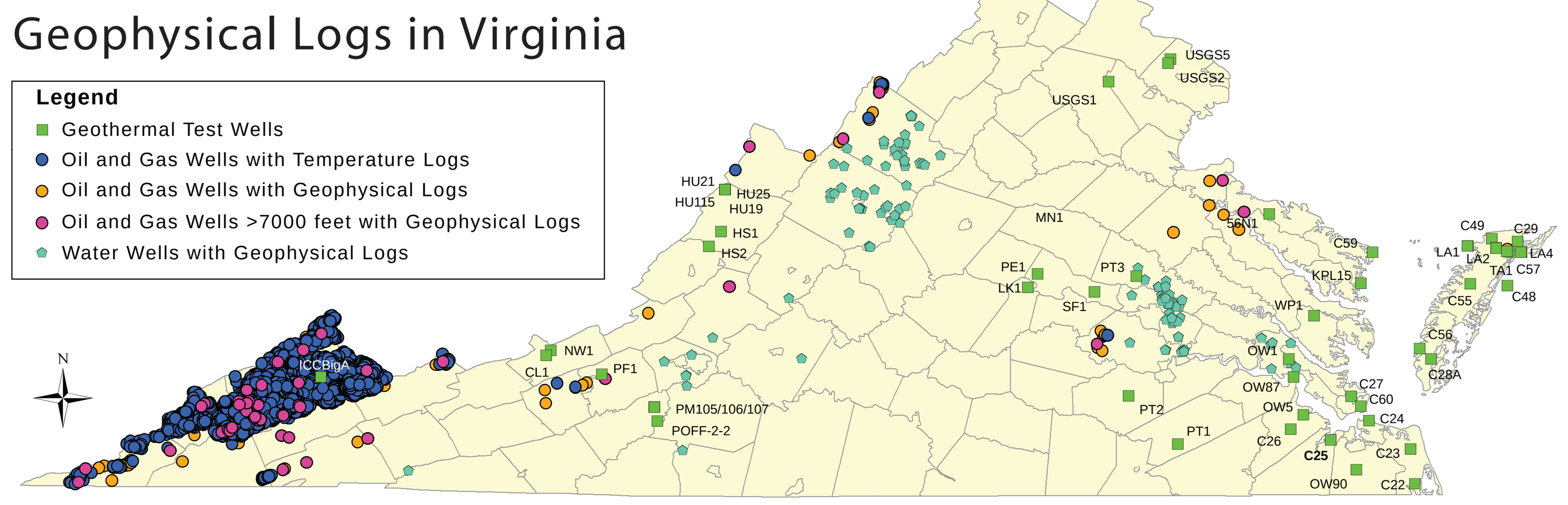


Figure shows locations of springs greater than 60°F with faults highlighted.
Base map from 1:500,000 scale Geologic Map of Virginia
Virginia Department of Mines, Minerals and Energy, 1993

Selected Wells with Geophysical Logs in Virginia



The Radiogenic Model

Optimum sites for low-temperature (< 300°F) geothermal resources in the tectonically stable eastern United States will probably be associated with crustal igneous rocks that contain relatively high concentrations of the heat-producing radioactive isotopes of uranium, thorium, and potassium. Moderate amounts of heat-producing isotopes occur in all crystalline basement rocks, but the principal geothermal targets in the southeastern U.S. are the relatively young (257-330 Ma) syn- and postmetamorphic U- and Th-bearing, heat-producing granitoid bodies that were intruded into the crystalline basement of the now-exposed Piedmont. They also occur in the basement beneath the sediments of the Atlantic Coastal Plain. The sediments, because of their low thermal conductivity, act as a thermal insulator, like a sweater. Granitoids crop out over a large area of the central and southern Appalachian Piedmont and Blue Ridge, and extend eastward in the basement rocks concealed beneath the sediments of the Atlantic Coastal Plain. A conspicuous negative Bouguer gravity anomaly is generally associated with the granitoid. The combination of relatively high heat flow from a heat-producing granitoid concealed beneath sediments of relatively low thermal conductivity was defined by Costain and others (1980) as the **radiogenic model**.

The model was confirmed at the Portsmouth, VA, drill site C25, where a -40 mgal Bouguer gravity anomaly near Portsmouth, Virginia was believed to be caused by a granite body beneath the sediments of the Atlantic Coastal Plain. Hole C25 was drilled into a late Alleghanian, unmetamorphosed, heat-producing granite and produced higher temperatures than in nearby hole C26, which was drilled into non-granitic, non-heat-producing, metamorphosed country rock into which the granite was intruded. For example, at a depth of ~500m/1640ft, the temperature in C25 is about 8°C/12.6°F higher than in C26. These higher temperatures are a direct result of the extra heat produced by the radioactive decay of U, Th, and K (about 80% of the heat comes from U and Th) in the granite beneath C25. The optimum sites for geothermal resource development are therefore over such granite bodies because higher temperatures are reached at shallower depths. Where the granites are concealed beneath Coastal Plain sediments, or where they do not reach the top of crystalline basement they can be located by geophysical exploration using gravity and magnetics (Costain, et al., 1980).

Acknowledgments

This on-going project is made possible by the assistance of a wide spread and multi-disciplinary team. Many thanks to DMME staff William L. Lassetter and David Spears for their continued support throughout this project; to assistants R.J. Hill, Curtis Romanchok, and Jessee Standbridge for their dedication to data compilation and preservation; to Virginia Department of Environmental Quality staff Brad White and Joel Maynard for assistance locating springs and water well data; to John K. Costain, emeritus professor of Geophysics at Virginia Tech, for his initial research and data collection and continued support as consultant on this project; to Wendy McPherson at the USGS in
Maryland, Dave Bolton, Lamere Hennessee, and Jim Reger at the Maryland Geological Survey, John Talley and Laura Wisk at the Delaware Geological Survey, Stephen Engerrand at the Georgia Archives, Lester Williams at the USGS in Georgia, and Jim Kennedy, Susan Kibler, and Steve Walker at the Georgia Department of Natural Resources for their willingness to track down archival information and contribute data to this project.

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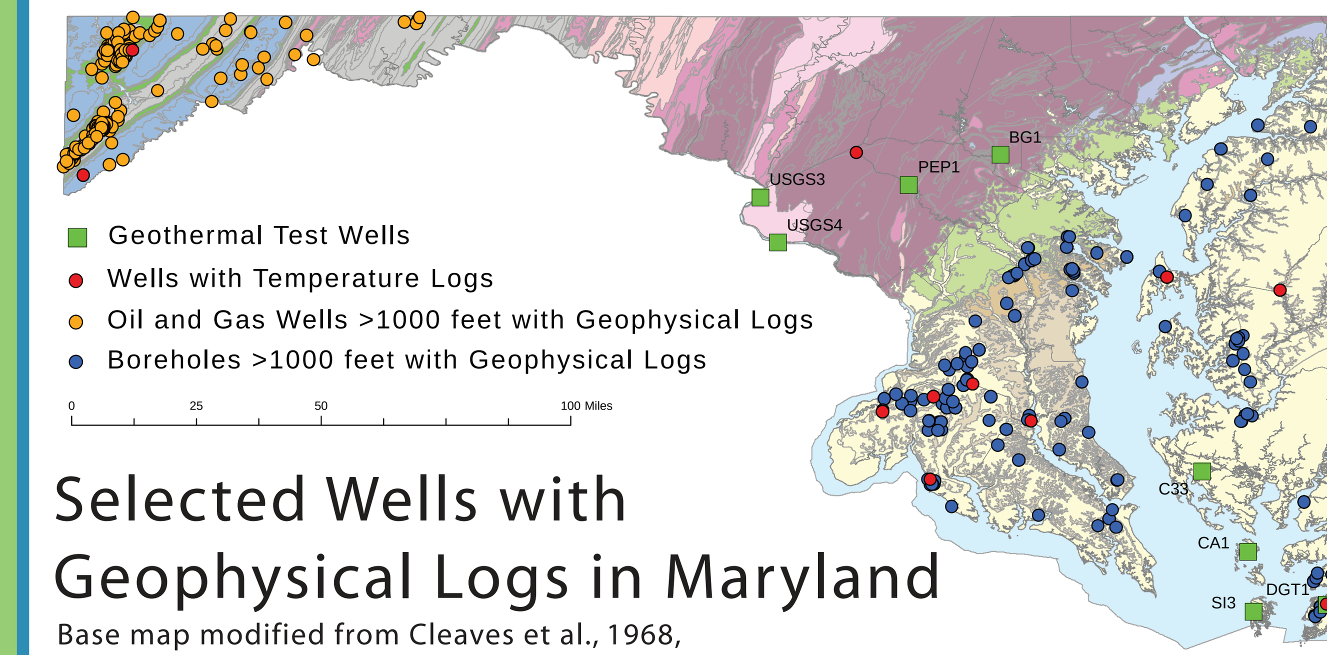
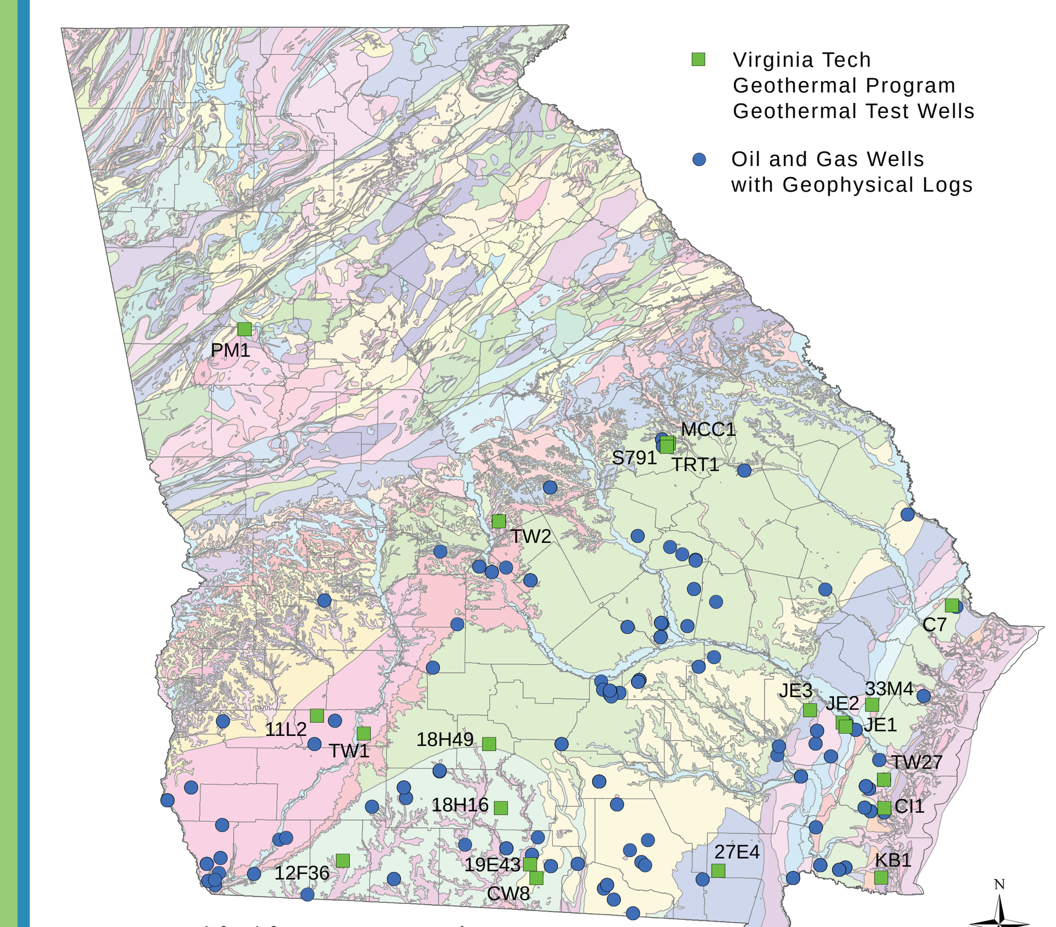
Selected Wells with Geophysical Logs in Maryland

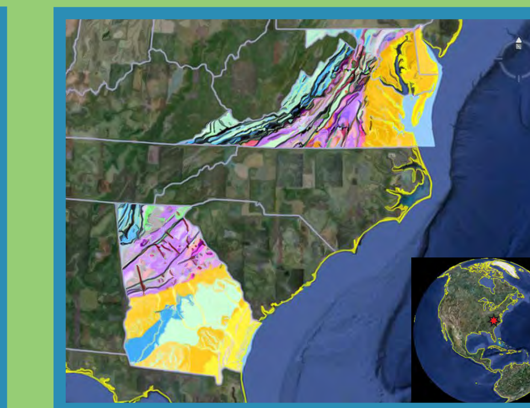


Base map modified from Cleaves et al., 1968, Geologic Map of Maryland, 1:250,000 scale.

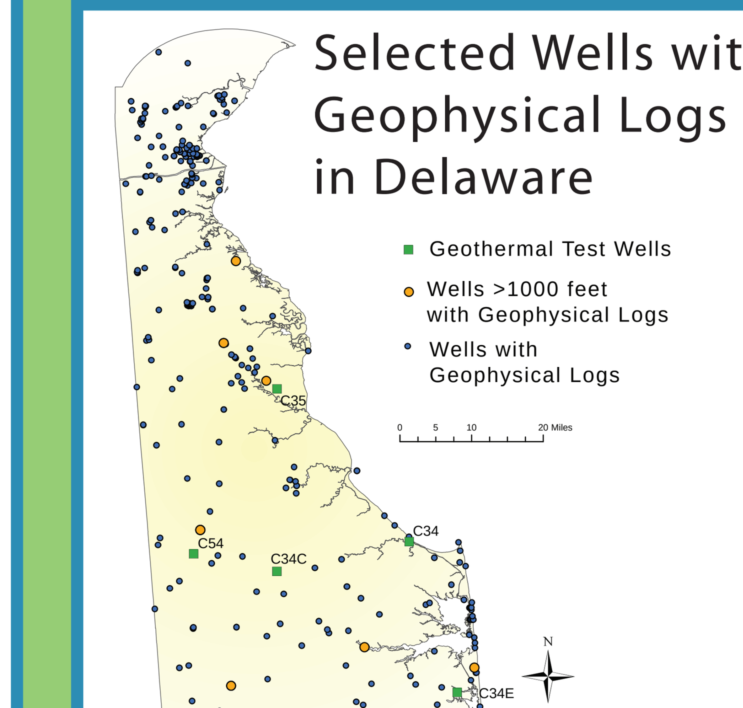
Selected Wells with Geophysical Logs in Georgia



Base map modified from Lawton et al., 1976, Geologic Map of Georgia, 1:500,000 scale.



Selected Wells with Geophysical Logs in Delaware



METHODS

	DE	GA	MD	VA
Borehole lithology logs (geothermal test wells)	• Extract lithology logs from geothermal Publication Scans and OCR • Enter 5 logs into database with depth intervals and lithologic descriptions • Link depth interval table to Geothermal Test Well attributes • Write metadata for 5 wells	• Extract lithology logs from geothermal Publication Scans and OCR • Enter 27 logs into database with depth intervals and lithologic descriptions • Link depth interval table to Geothermal Test Well attributes • Write metadata for 27 wells	• Extract lithology logs from geothermal Publication Scans and OCR • Enter 19 logs into database with depth intervals and lithologic descriptions • Link depth interval table to Geothermal Test Well attributes • Write metadata for 19 wells	• Extract lithology logs from geothermal Publication Scans and OCR • Enter 50 logs into database with depth intervals and lithologic descriptions • Link depth interval table to Geothermal Test Well attributes • Write metadata for 50 wells
Borehole lithology log (water wells)	• Contact John Talley, UDel, 302-831-2833, for well information • Locate DE Publications with lithology logs in them (water well and deep test wells) • Scan all DE Publications, OCR pdfs, and extract lithology logs • QC scans of lithology logs in QC checklist • Link lithology logs to DEWaterWellRecords database • Choose 200 logs to enter depth intervals and lithology descriptions into database and link to Water Well attributes • Write metadata for 200 water wells	• Contact Lester Williams, USGS, 404-906-5761, for deep water well information in NW GA • Locate GA Publications with water well lithology logs in them (GGS Bull 70 & 74) • Scan all GA Publications, OCR pdfs, and extract lithology logs • QC scans of lithology-logs in QC checklist • Link lithology logs to GAWaterWellRecords database • Choose 100 logs to enter depth intervals and lithology descriptions into database and link to Oil and Gas attributes • Write metadata for 100 water wells	• Locate MD Publications with water well lithology logs in them • Scan all MD Publications, OCR pdfs, and extract lithology logs • QC scans of lithology-logs in QC checklist • Link lithology logs to MDOilandGasRecords database • Choose 100 logs to enter depth intervals and lithology descriptions into database and link to Oil and Gas attributes • Write metadata for 100 water wells	• Scan all G-Logs and OCR all pdfs • QC scans of G-logs in QC checklist • Link G-Logs to Water Well Records Database and Well Cuttings Database • Choose 200 logs to enter depth intervals and lithology descriptions into database and link to Water Well attributes • Write metadata for 200 water wells
Borehole lithology logs (oil and gas wells)		• Contact Lester Williams, USGS, 404-906-5761, for oil and gas well information • Locate GA Publications with oil and gas well lithology logs in them (GGS Bull 70 & 74) • Scan all GA Publications, OCR pdfs, and extract lithology logs • QC scans of lithology-logs in QC checklist • Link lithology logs to GAOilandGasRecords database • Enter depth intervals and lithology descriptions into database and link to Water Well attributes • Write metadata for oil and gas wells	• Locate MD Publications with oil and gas lithology logs in them • Scan all MD Publications, OCR pdfs, and extract lithology logs • QC scans of lithology-logs in QC checklist • Link lithology logs to MDWaterWellRecords database • Choose 50 logs to enter depth intervals and lithology descriptions into database and link to Water Well attributes • Write metadata for 50 wells	• Scan all geologic lithology logs in Oil and Gas Records File Room and OCR • QC scans of lithology logs • Link logs to WellSum database and Well Cuttings database • Choose 200 logs to enter depth intervals and lithology descriptions into database and link to Oil and Gas Well attributes • Write metadata for 200 wells
Digital well logs (geothermal test wells)	• Scan 5 geophysical logs and convert to LAS file • Link scans and LAS files to Geothermal Test Well attributes in database • Write metadata or 5 logs	• Scan 27 geophysical logs and convert to LAS file • Link scans and LAS files to Geothermal Test Well attributes in database • Write metadata or 27 logs	• Scan 19 geophysical logs and convert to LAS file • Link scans and LAS files to Geothermal Test Well attributes in database • Write metadata or 19 logs	• Scan 50 geophysical logs and convert to LAS file • Link scans and LAS files to Geothermal Test Well attributes in database • Write metadata or 50 logs
Digital well logs (water wells)	• Contact John Talley, UDel, 302-831-2833, for well information • Locate DE Publications with geophysical logs in them (water well and deep test wells) • Scan all DE Publications, OCR pdfs, and extract lithology logs • QC scans of geophysical logs in QC checklist • Link geopysical logs to DEWaterWellRecords database • Enter interval information into database table • Write metadata for 100 water wells digital logs	• Obtain geophysical logs list for water wells from Lester Williams, USGS, 404-906-5761 • Enter GA well information into GAWaterWellRecords database • Gather existing scans from USGS and GGS then identify remaining logs to be scanned • Link scanned digital logs to water well attributes in GAWaterWellRecords database • Enter interval information into database table • Write metadata for 100 water well digital logs	• Use MGS_MASTER_LOG_LIST spreadsheet to sort well information • Enter MD well information into MDWaterWellRecords database • Gather existing scans from MGS and Maryland USGS and identify remaining logs to be scanned • Link scanned digital logs to water well attributes in MDWaterWellRecords database • Enter interval information into database table • Write metadata for 100 water well digital logs	• Scan all E-Logs • QC scans of E-Logs • Link E-logs to Water Well Records database • Enter interval information into database table • Write metadata for 100 water well E-Logs • Scan all Water Well Location Maps and Georeference in ArcGIS • Digitize Location of Wells • Enter Ledger info into Water Well Records database • Link Ledger info to lat/long locations
Digital well logs (oil and gas wells)		• Use GA_Wells_Data to sort oil and gas well information • Enter GA well information into GAOilandGasRecords database • Gather existing scans from USGS and GGS then identify remaining logs to be scanned • Link scanned digital logs to oil and gas well attributes in GAOilandGasRecords database • Write metadata for oil and gas digital logs	• Use "Deep Wells of Maryland" publication and MGS_MASTER_LOG_LIST spreadsheet to sort well information • Enter MD well information into MDOilandGasRecords database • Gather existing scans from MGS and Maryland USGS and identify remaining logs to scan • Link scanned digital logs to oil and gas well attributes in MDOilandGasRecords database • Write metadata for 7 digital logs	• Scan any remaining geophysical logs • QC existing scans and complete inventory sheet • Re-scan any necessary logs for higher resolution for future vectorization • Link scans to WellSum2011 database • Populate "WellFiles_Data" table in WellSum2011 database with interval data • Write metadata for 200 logs
Temperature depth logs (geothermal test wells)	• Enter temp/depth log measurements into Geothermal Test Well database • Write metadata for 5 logs	• Enter temp/depth log measurements into Geothermal Test Well database • Write metadata for 27 logs	• Enter temp/depth log measurements into Geothermal Test Well database • Write metadata for 19 logs	• Enter temp/depth log measurements into Geothermal Test Well database • Write metadata for 100 logs
Documents and References	• Link online locations and scans to Reference database • Write metadata for 30 references	• Contact Susan Kibler, GEPD, 404-463-5294 to submit scans of GGS Publications • For documents not found in DGMR Library, obtain permission to scan documents onsite • Scan all available publications, OCR, and enter into Reference database • Link online locations and scans to Reference database • Write metadata for 30 references	• Contact Maryland State Archives for scans of MGS Publications • Obtain permission to scan documents onsite • Scan all available publications, OCR, and enter into Reference database • Link online locations and scans to Reference database • Write metadata for 30 references	• Scan all publications, OCR, and enter into Reference database • Link online locations and scans to Reference database • Write metadata for 30 references • Re-stock all paper publications back onto DGMR Library shelves
Geologic Maps (1:24,000 scale)	• Create index of all 1:24,000 scale geologic maps created in DE • 12 DGS maps scanned, online; 5 are digital online • Link location of all accompanying reports to spreadsheet • Write metadata for 12 geologic quadrangle maps	• Contact Stephen Engerrand,GA Archives, 678-364-3714, and Susan Kibler, GEPD, 404-463-5294 for current status of scanned geologic maps • Create index of all 1:24,000 scale geologic maps created in GA • 8 USGS maps scanned, online; 20 GGS maps not scanned, not online • Obtain permission to scan remaining 24k maps and make available online • Link location of all accompanying reports to spreadsheet • Write metadata for 28 geologic quadrangle maps	• Contact Lamere Hennessee 410-554-5519 for current status of scanned geologic maps • Create index of all 1:24,000 scale geologic maps created in MD • 16 USGS maps scanned, online; 1 USGS map not scanned, online; 19 MGS maps scanned, not online; 40 MGS maps not scanned, not online (19 in DGMR library, not scanned); 1 WVGS map not scanned • Obtain permission to scan remaining 24k maps and make available online • Link location of all accompanying reports to spreadsheet • Write metadata for 77 geologic quadrangle maps	• Create index of all 1:24,000 scale geologic maps created in VA • Link location of maps to Published_24k_2010 shapefile • Link location of all accompanying reports to shapefile • Write metadata for 253 geologic quadrangle maps
Geologic Unit Descriptions (with geothermal characterization)	• Collect detailed descriptions of all geologic units on DE State Map (use USGS, Google Earth kmz file, and DGS website) • Link Costain's thermal conductivity measurments to rock formations • Write metadata for 54 unit descriptions, including links to descriptions	• Collect detailed descriptions of all geologic units from 1976 GA State Map (use USGS and Google Earth kmz file) • Link Costain's thermal conductivity measurments to rock formations when possible • Write metadata for 172 unit descriptions, including links to descriptions	• Collect detailed descriptions of all geologic units from 1968 MD State Map (use USGS and Google Earth kmz file) • Link Costain's thermal conductivity measurments to rock formations when possible • Write metadata for 92 unit descriptions, including links to descriptions	• Collect detailed descriptions of all geologic units from 1993 VA State Map and corresponding links (use Hannah's work, USGS and Google Earth kmz file) • Link Costain's thermal conductivity measurments to rock formations • Write metadata for 300 unit descriptions, including links to data
Hot Spring Descriptions		• Use "Mineral Springs of GA" Bull 20 to collect data for every spring around GA with ≥ 60°F (lat, long, flow rate, water temp, water chemistry when available) • Cite references in spreadsheet/shapefile • Write metadata for 7 thermal springs	• Use MGS RI-42 to collect data for every spring around MD with ≥ 60°F (lat, long, flow rate, water temp, water chemistry when available) • Cite references in spreadsheet/shapefile • Write metadata for thermal springs	• Collect data for every spring around VA with ≥ 60°F (lat, long, flow rate, water temp, water chemistry when available) • Cite references in spreadsheet/shapefile • Write metadata for 28 thermal springs
Bottom Hole Temperatures	• Collect BHT measurements off geophysical logs for any oil, gas, water, or geothermal test wells • Link BHT to well attributes in database • Write metadata for 100 BHT measurements	• Collect BHT measurements off geophysical logs for any oil, gas, water, or geothermal test wells • Link BHT to well attributes in database • Write metadata for 100 BHT measurements	• Collect BHT measurements from geophysical logs for 19 geothermal test wells • Collect BHT measurements from geophysical logs for 100 water and oil and gas wells • Link BHT to well attributes in databases • Write metadata for 119 BHT measurements	• Collect BHT measurements from geophysical logs for any oil, gas, water, or geothermal test wells • Link BHT to well attributes in database • Write metadata for 300 BHT measurements
Heat Flow Measurements (geothermal test wells)	• Collect direct heat flow measurements from geothermal test wells • Enter in database • Write metadata for 5 heat flow measurements	• Collect direct heat flow measurements from geothermal test wells • Enter into database • Write metadata for heat flow measurements	• Collect direct heat flow measurements from geothermal test wells • Enter into database • Write metadata for heat flow measurements	• Collect direct heat flow measurements from geothermal test wells • Enter into database • Write metadata for 77 heat flow measurements
Thermal Conductivity Measurements	• Collect Thermal Conductivity of rocks from geothermal test well samples from VTech • Link Thermal Conductivity of rocks to formations on DE State Geologic Map • Write metadata for Thermal Conductivity measurements	• Collect Thermal Conductivity of rocks from geothermal test well samples from VTech • Link Thermal Conductivity of rocks to formations on GA State Geologic Map • Write metadata for Thermal Conductivity measurements	• Collect Thermal Conductivity of rocks from geothermal test well samples from VTech • Link Thermal Conductivity of rocks to formations on MD State Geologic Map • Write metadata for 5 Thermal Conductivity measurements	• Collect Thermal Conductivity of rocks from geothermal test well samples from VTech • Link Thermal Conductivity of rocks to formations on VA State Geologic Map • Write metadata for 100 Thermal Conductivity measurements

References

Arizona Geological Survey Geothermal Website:
http://www.azgs.state.az.us/geothermal_ngds.shtml
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Costain, J.K., L. Glover, III, and A.K. Sinha, 1982, Geothermal Energy for the Eastern United States, Virginia Minerals, v. 28, no. 2.
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National Geothermal Database Website: http: //www.geothermaldata.org/
Virginia Tech Geothermal Program Website: http://rglsun1.geol.vt.edu/