

## Appendix B: Glossary

This glossary contains simplified definitions of geologic and technical terms and acronyms used in this report. Most words are defined relative to their use in carbon storage research. A good source for definitions for geological terms is J.A. Jackson's "Glossary of Geology" (1997). Good online resources include the University of California at Berkeley's geology glossary ([www.ucmp.berkeley.edu/glossary/gloss2geol.html](http://www.ucmp.berkeley.edu/glossary/gloss2geol.html)) and Cengage Learning's Geolink glossary at ([college.cengage.com/geology/resources/geologylink/glossary.html](http://college.cengage.com/geology/resources/geologylink/glossary.html)). The source for most of the oil and gas field definitions is the Schlumberger oil field glossary ([www.glossary.oilfield.slb.com](http://www.glossary.oilfield.slb.com)).

- Acidize.** A common method of well treatment or well stimulation where hydrochloric acid is pumped under pressure into a specific rock reservoir composed of carbonate rocks or having carbonate cement, in order to increase the permeability of the reservoir near the wellbore and increase the flow of fluids or gases out of the reservoir into the well. The acidizing treatment is sometimes referred to as an *acid job*.
- Adsorption.** The adhesion of liquid or gas molecules onto a solid surface. For example, CO<sub>2</sub> molecules will adsorb onto carbon-rich surfaces, such as are found in coal or carbon-rich black shales. *Adj. Adsorptive.*
- Anion.** An ion with a negative charge.
- Anticline.** A geologic structure in which rock units are folded in a convex-upward configuration, such that the elevation of a rock unit along the axis of the fold is greater than the elevation of the rock unit on either flank. These structures are smaller scale than regional arches. The opposite type of structure is a *syncline*.
- Aquifer (general).** An underground layer of permeable rock or sediment that can yield significant quantities of water to a well or spring. Water generally is held in the pore spaces between mineral grains of the rock or sediment. Freshwater aquifers occur near the surface at relatively shallow depths and must, by law, be protected from contamination. *Saline reservoirs* are saltwater (brine)-bearing rock units that occur at depth and are potential carbon storage reservoirs.
- Arch.** A regional geologic structure in which rock units are folded upward, such that the elevation of a rock unit along the axis of the arch is greater than the elevation of the rock unit on either flank. Arches are similar to, but are typically larger scale than, anticlines. Arches may separate basins.
- Argillaceous.** Adjective used to describe rock or sediment that contains significant amounts of clay-size particles (shaly). Very fine-grained particles can clog pore spaces and decrease permeability in reservoirs.
- Arkose.** A type of sandstone containing at least 25 percent feldspar. It is typically pink or red and usually derived from rapid weathering of granitic rocks. In fact, sample cuttings from deep Cambrian arkoses have been misidentified as granites in some wells. Arkoses are typical of Precambrian and lowest Cambrian sediments in Kentucky. The relatively high potassium content in arkoses causes higher than normal gamma readings on subsurface geophysical logs, which can be misinterpreted as shaly zones. *Adj. Arkosic*
- Basalt.** A dark-colored (mafic) igneous (intrusive or extrusive) rock formed from lava. Basalts are a possible carbon storage reservoir where they have porosity. Carbon could theoretically be stored through mineral trapping in basalts. Basalts occur at depth in the Precambrian Middle Run Formation in Kentucky.
- Basement.** General term for Precambrian rocks in the subsurface. The term is informally used to differentiate dominantly igneous and metamorphic rocks of the Precambrian from the layered sedimentary rocks above. In some parts of Kentucky, the basement also contains thick Precambrian sedimentary rocks. The term "crystalline basement" may be used for Precambrian igneous and metamorphic rocks to aid in differentiating them from Precambrian sedimentary rocks.
- Basement fault.** A fault that extends into the Precambrian (basement) rocks. Sometimes referred to as faults "rooted in basement."
- Basin.** A structurally low or depressed area in the earth's crust in which thick sequences of sedimen-

tary rock accumulated. Typically, they are large regional areas that had or have persistent subsidence for periods of geologic time.

**Below drainage.** Term used to define depth below the lowest level of a stream in an area. In hilly or mountainous terrain it is often important to designate depth below the lowest drainage, rather than depth below the surface, since wells drilled at the top of hills or mountains may be well above the lowest surface drainage to the side of the hill or mountain.

**Bentonite.** A clay layer composed chiefly of the clay mineral montmorillonite (smectite), which is usually derived from altered volcanic ash. Because smectites swell in water, bentonite layers can form confining beds that prevent vertical migration of liquids. Bentonite is commercially used as a drilling mud.

**Bioturbation.** Features in rocks or sediment that indicate the sediment was disturbed or inhabited by organisms, including churning, burrows, tracks, and trails. Some types of burrows are indicative of the original depositional environment of the rock. This feature is more common in marine than nonmarine rocks. Burrows commonly have different fills than surrounding rock, which can influence porosity and permeability. *Adj. Bioturbated.*

**Brecciated.** In geology, a rock fabric consisting of angular or broken rock fragments in a matrix or cement. The rock is called a *breccia*.

**Brine.** Formation water that has salinity significantly greater than seawater (35,000 mg/L TDS).

**Calcite.** A common rock-forming mineral composed of calcium carbonate ( $\text{CaCO}_3$ ). Calcite is common in carbonate rocks but can occur in other rocks as well.

**Carbon dioxide ( $\text{CO}_2$ ).** A molecule consisting of one carbon atom covalently bonded to two oxygen atoms. At earth surface temperatures and pressures it exists as a gas and it comprises about 0.04 percent of atmospheric gas. It is one of the main greenhouse gases, and its atmospheric concentration has risen coincident with the industrial revolution. Carbon dioxide is nontoxic and an important part of the global carbon cycle, in which it is produced by a large number of natural and man-made sources.

es. Man-made sources include combustion of hydrocarbons for electricity and transportation fuel, cement manufacturing, and ethanol production.

**Carbon sequestration, carbon storage.** A technology or process that captures carbon dioxide from man-made emissions or the atmosphere and stores them in the biosphere (plants and animals), lithosphere (earth), or hydrosphere (ocean sequestration). Terrestrial carbon sequestration uses properties of the soil and plants to remove or store carbon dioxide. Geologic carbon sequestration involves the injection of carbon dioxide into subsurface rock units such as unmineable coals, depleted oil and gas reservoirs, carbon-rich shales, or saline reservoirs.

**Carbonate.** General term for rocks composed of rocks rich in carbonate ( $\text{CO}_3^{2-}$ ) such as limestone ( $\text{CaCO}_3$ ) and dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ), and sometimes rocks cemented by calcite. Carbonate rocks are generally more reactive to  $\text{CO}_2$ -saturated brine than noncarbonate rocks.

**Carbonic acid.** A weak acid formed by the dissolution of  $\text{CO}_2$  in water. Carbonic acid is formed by the reaction  $\text{CO}_2 + \text{H}_2\text{O} = \text{H}_2\text{CO}_3$ .

**Casing (case the well).** Pipe that is lowered into a wellbore and cemented in place. Casing is placed in wells in order to isolate parts of the wellbore from surrounding rocks and fluids. In most wells, it is required through at least the intervals of fresh water in order to protect any freshwater aquifers from drilling fluids or gases. Casing may also be used deeper downhole to isolate other rock units as needed, stabilize the wellbore, or to control pressure and fluid flow. Putting casing in the ground is called “running pipe” or “casing the well.”

**Cation.** An ion with a positive charge.

**CBM.** *See coalbed methane.*

**Cement (rock).** Natural mineral binding material that welds framework grains together in a rock. There may be several types of cement in a sedimentary rock.

**Cement (well).** Material used during drilling to bind casing to the wellbore.

**Cement bond log.** A type of geophysical well log that uses acoustic measurements to graphically image the cement used to hold the wellbore casing in

place in a drillhole. The purpose of the log is to analyze the cement for holes that would diminish the ability of the cement to prevent fluid movement between the casing and borehole wall. The annulus between the rock wall of the borehole and the casing installed in a well.

**Chert.** A hard, microcrystalline quartz-rich rock. Chert is harder to drill through than many other rock types, so rocks with abundant chert may require longer to drill through or cause well deviations.

**Chlorite.** A silicate (phyllosilicate) mineral group associated with low- to medium-temperature metamorphic rocks or hydrothermal deposits. An iron-aluminum-magnesium-silicate hydroxide mineral.

**Clean (sandstone).** Adjective used by drillers to describe a relatively pure or homogeneous sandstone, typically quartz-rich or quartzose in contrast to a sandstone composed of many different kinds of grains, which appears speckled or “dirty.”

**Closure.** *See structural closure.*

**Coalbed methane (CBM).** Natural gas (methane) held within and produced from coal beds. Carbon dioxide might be used to enhance coalbed-methane recovery. Because the coals are carbon-rich, the carbon dioxide should be adsorbed (stick) onto the coal matrix.

**Completion (well completion, complete a well).** Finishing a well so it is ready to produce oil or gas. This usually involves installing production casing and cement, perforating the casing into the producing interval, treating the producing interval, running production tubing, and installing pumps, etc., for production. When examining well records, a completion indicates that there were sufficient hydrocarbons (and presumably porosity and permeability in the host reservoir) to go to the expense of installing tubing, etc.

**Condensate.** Volatile hydrocarbons often co-produced with natural gas that are liquid at surface temperature and pressure conditions: “wet gas.” These generally are high-gravity oils.

**Conductivity.** A measurement used to approximate the salinity of a formation water sample. In general, as the number of ions in a formation water increases, the conductivity increases. Measured in Siemens

or milliSiemens, conductivity is the reciprocal of resistivity.

**Confining interval (zone).** An impermeable rock interval or zone that does not allow vertical migration of fluids or gas from underlying reservoirs. Adequate confining intervals must be demonstrated to regulatory agencies for permitting an underground injection well. There may be multiple confining intervals above injection reservoirs. Also known as a *caprock* or *seal*.

**Core.** A cylindrical section (sample) of rock removed through drilling with a special bit and drill rig. *Full (whole or conventional) core* is cut at near the diameter of the wellbore (generally 3 to 5 in.) during drilling and is recovered in vertical sections, usually in 30-ft increments. *Sidewall cores* are much smaller cores (generally 1-in. diameter and several inches in length) drilled horizontally from the wellbore after a well has been drilled. Cores provide actual samples of rock strata for reservoir testing and analysis.

**Crop out.** Exposed at the surface.

**Crystalline rock, crystalline basement.** Metamorphic or igneous rocks, generally in deep Precambrian strata. In much of the Midwest, crystalline rocks form the bottom (basement) on which younger sedimentary rocks were deposited. The overlying sedimentary rocks contain reservoirs for oil, gas, water, and possibly carbon sequestration.

**Cuttings.** Fragments and chips of rocks that are cut from the wellbore by drilling. The chips are brought up the hole to the surface as part of normal drilling operations, are screened from the drilling mud, and then described by drilling personnel. Descriptions may include information about their apparent composition, color, texture, hydrocarbon content (if any), and depth. Cuttings are bagged and saved for some wells. The Kentucky Geological Survey Well Sample and Core Library has a large inventory of cutting samples from many of the deep wells in Kentucky.

**Darcy.** Standard measure of permeability that is equal to the passage of 1 cm<sup>3</sup> of fluid of 1 centipoise viscosity flowing in 1 sec under a pressure differential of 1 atmosphere through a porous medium having

a cross-section area of 1 cm<sup>2</sup> and length of 1 cm (see millidarcy).

**Density log.** A type of geophysical well log that shows a graphic representation of the bulk density of rocks and their contained fluids in close proximity to the wellbore. Density measurements are taken by a wireline tool that is lowered down the well. Porosity can be calculated based on a mass-balance relationship between bulk density and porosity.

**Detrital.** Grains that have been eroded from other rocks or organic material.

**Diagenesis.** The sum of all of the biological, chemical, and physical alteration of sediment after its burial, and as it turns to stone (lithification), but not including weathering and erosion when the rock is reexposed at the surface.

**Dissolution.** A type of chemical weathering in which water or acidic waters dissolve parts of minerals or rocks from the surrounding bedrock. Most common in carbonate rocks.

**DOE.** U.S. Department of Energy. This federal organization oversees carbon capture and sequestration research in the United States.

**Dolomite.** A sedimentary rock dominated by the mineral dolomite, which is a magnesium-rich, rather than calcium-rich, carbonate rock. In some cases, the term *dolostone* is used to differentiate the sedimentary rock referred to as dolomite from the mineral dolomite. *Adj. Dolomitic.*

**Dolomitization.** The process by which a carbonate rock is altered to dolomite. This can occur during sedimentation or shortly after burial, as in arid shoreline (sabkha) environments, or can occur later in burial through the migration of hot, mineral-rich fluids through carbonate rocks.

**Drillstem test (DST).** A standard formation or reservoir test in which a subsurface interval of rock is isolated (usually by packers down the wellbore) and fluid is allowed to flow from the formation into the drillstem and pressures are recorded over time. A variety of pressure responses can be tested by opening and closing valves that allow fluids to flow into the drillstem.

**Enhanced gas recovery (EGR).** The stage of gas recovery in which a variety of methods can be used

to displace residual natural gas in a reservoir so it can be more easily extracted.

**Enhanced oil recovery (EOR).** The third stage of oil recovery, in which a variety of methods can be used to alter the chemical or physical properties of the remaining oil in a reservoir so it can be more easily extracted. EOR typically involves injecting fluids or gases into a reservoir or heating the reservoir in order to lower the viscosity (stickiness) of the remaining trapped oil. Differs from *secondary recovery*, where the goal is repressurization or pressure stabilization in the reservoir with the simple intent to displace additional oil. Miscible CO<sub>2</sub> could be injected into old oil reservoirs in order to lower the viscosity of stubborn trapped oil, allowing it to flow to a producing well.

**EPA.** U.S. Environmental Protection Agency. The EPA has primacy over underground injection in Kentucky. Any underground injection control permit (typically referred to as a UIC permit) must be approved by EPA Region IV offices in Atlanta, Ga.

**Equation of state.** Functions that describe the values of pressure (P), temperature (T), and volume (V) for phases (gas, liquid, solid, or some combination) at equilibrium; that is, no net change in the properties or composition of the system without an external influence.

**Facies.** The recurrent and persistent assemblage of rock type, fossils, and thickness that characterize strata of a specific origin. Facies are typically used to describe parts of sedimentary rock bodies. A rock *formation* will generally consist of several different facies. Each facies may have its own porosity and permeability characteristics.

**Fault.** A crack in the earth's crust across which movement has occurred. The fault is a geometric plane between two rock masses. See *normal*, *reverse*, *strike-slip*, and *thrust* fault for different types of faults defined by the relative movement of rock masses on either side of the fault. *Sealing* and *transmissive* faults refer to their ability to transmit fluids or gases. In carbon storage research it is very important to identify any fault within the area of potential injection.

**Feldspar.** A group of common rock-forming minerals composed of aluminum and silica (aluminosili-

ates) with potassium, sodium, and calcium. *Adj. Feldspathic.*

**Feldspathic.** Adjective used to describe a rock containing abundant feldspar grains.

**Felsic.** Adjective used to describe the light-colored, silica and aluminum minerals in igneous rocks.

**FDC (compensated formation density) log.** A type of geophysical well log that shows a graphic representation of the bulk density of rocks and their contained fluids along the sides of the wellbore, which has been corrected (compensated) for fluctuations in the diameter of the borehole and the influence of drilling fluids and mud cake downhole. Density measurements are taken by a wireline tool that is lowered down the well. Porosity can be calculated based on a mass-balance relationship between bulk density and porosity.

**Formation (rock unit).** The basic rock unit used for mapping in geology. Formations have distinctive upper and lower boundaries and must be mappable for large distances. Formations may be composed of smaller units termed *members* and *beds*. Multiple formations may be combined into larger units called groups.

**Formation water.** Water present in the porosity of subsurface reservoirs or other types of buried rocks—typically sedimentary.

**Frac, fracing, fracking.** *See hydraulic fracture.*

**Fracture (frac) pressure.** The pressure at which a unit of rock fractures. This pressure must be calculated and tested for any injection well in order to determine the limits of injection pressure that will be allowed so that overlying confining intervals are not fractured.

**Fracture gradient.** The pressure at which a rock formation will fracture at different depths in the subsurface, typically noted as pressure per unit depth (for example, psi/ft=pounds per square inch per foot).

**Framework grains.** The grains that are the principal supporting structure in sedimentary rocks. Framework grains may consist of a single mineral (e.g., quartz grains), rock fragments, or fossil grains. The intervening space between the framework

grains—the pore space—can be entirely or partly filled with cement or matrix.

**Friable (sandstone).** Adjective used to describe a rock that is poorly cemented and easily broken or crumbled.

**Fugacity.** Describes the effective concentration of gases under nonideal conditions (that is, high pressure), in which molecules react more strongly with other molecules.

**FutureGen.** A federal- and industry-sponsored project to construct the first near-zero-emissions power plant. The plant would use geologic carbon sequestration as part of a strategy to mitigate carbon emissions.

**Gamma-ray log.** A type of geophysical well log that shows a graphical representation of natural gamma-ray emissions from subsurface rock units. Measurements are taken by a wireline tool lowered down a wellbore. Useful for identifying shales because shales emit more gamma rays than other common rock units.

**Gas-drive reservoirs.** Reservoirs in which the primary recovery mechanism is dissolved and frees natural gas in the reservoir. Expansion of the gas is used to drive the oil from the reservoir into the wellbore.

**Geophysics.** The study of the physics of the earth, primarily through seismic, gravitational, magnetic, radioactive, or electrical means. In geology, geophysics refers to a wide array of techniques used to directly or passively gather information from beneath the surface of the earth. *Adj. Geophysical.*

**Geophysical well log (well log).** General term for a recording or measurement of subsurface rock and fluid properties gathered from a wireline tool lowered down a wellbore using geophysical techniques, such as measurements of spontaneous potential and resistivity (electric logs), or gamma ray and density (radioactivity), etc.

**Geothermal gradient.** The rate of increase of temperature in the earth with depth. The gradient varies by region, but the overall average gradient for the crust is 25°C per kilometer of depth.

**Gigatonne.** Metric unit equal to 1 billion metric tonnes or 1.103 billion U.S. tons (standard short tons).

Standard international unit used for measuring carbon dioxide emissions.

**Glauconite.** A green silicate mineral found in sedimentary rocks and consisting mostly of silica, potassium, and iron. Generally, characteristic of sediments deposited in deeper marine conditions at slow depositional rates. The high potassium content of this clay mineral can cause false porosity readings on neutron logs and high gamma readings.

**Graben.** A relatively downdropped block bounded by normal faults.

**Granite.** An intrusive igneous rock formed from magma and consisting of quartz (silica), feldspars, amphiboles, pyroxenes, and micas. In Kentucky, granites are known from subsurface Precambrian strata.

**Gravity data/surveys/analyses/anomaly.** Measurements of spatial variations in the earth's gravitational field. Measurements at different locations can be used to detect different densities of rock strata in the subsurface. Gravity *surveys* or *analyses* are done to map variations in the gravitational field. When mapped, *gravity anomalies* (rapid lateral changes in gravity measurements) may indicate changes in geology related to major faults or igneous intrusions.

**Greenhouse effect.** Heating (rising temperature) caused by greenhouse gases in the atmosphere that absorb and emit infrared radiation (heat).

**Greenhouse gases.** Gases in the earth's atmosphere that absorb and emit radiation from the thermal infrared range, including water, carbon dioxide, methane, nitrous oxide, and ozone. Although water is the most abundant greenhouse gas in the atmosphere, science indicates that small changes in the amount of carbon dioxide and methane (common in industrial and fossil-fuel-powered electrical-plant emissions) can cause increases in the earth's surface temperature, termed global warming, or global climate change.

**Group (rock unit).** A rock unit generally composed of two or more genetically related formations. This unit is designated when the formations in the group are more similar to or distinctive from each other than formations above or below the group.

**Hematite.** A red or silver iron-oxide mineral. *Adj. Hematitic.*

**Heterogeneous.** Adjective indicating variable characteristics. In sedimentary geology, heterogeneous usually denotes lateral variability in thickness, grain size, and bedding. The opposite is homogeneous. *Noun. Heterogeneity.*

**Homogeneous.** Adjective indicating relatively uniform characteristics. The opposite is heterogeneous. *Noun. Homogeneity.*

**Horst.** A relatively uplifted (positive) fault block bounded by normal faults. Horsts often bound grabens.

**Huff-and-puff.** In petroleum geology and carbon sequestration, an enhanced oil recovery method in which CO<sub>2</sub> is injected into an oil reservoir through a well. The well is then shut-in (closed) to let the injected CO<sub>2</sub> dissipate into the reservoir, potentially dissolving into the oil, the "soak" period. After some of time (determined by the bottom hole pressure) the well is opened to allow the oil to be produced. Several cycles of injection and shut-in (huff) followed by production (puff) may be used.

**Hydraulic fracture.** A well-stimulation method in which fluids are pumped into a reservoir at high pressure in order to overcome the natural confining pressure in the reservoir, causing a vertical fracture in the reservoir. The fracture is then filled (propped) with sand (or other material) to keep the fracture open. This method increases the hydraulic connectivity between the reservoir and the wellbore.

**Hydrocarbon.** An organic compound consisting of hydrogen and carbon. Typically refers to fuels such as natural gas, oil, and coal.

**Hydrology.** The study of water. In petroleum geology and carbon sequestration, hydrology involves the measurement and physical and chemical characterization of subsurface waters.

**Hydrostatic pressure and gradient.** The pressure exerted on a point overlain by a column of water at rest. The average hydrostatic gradient with depth in the earth is 100 bars/km or 0.43 lb/in.<sup>2</sup>/ft.

**Hydrothermal dolomite.** Dolomite formed by precipitation from water hotter than the surrounding rocks (hydrothermal fluids) in the subsurface.

**Hydrothermal fluids.** Fluids, often mineral-rich, which are heated within the earth. These fluids can move along faults and fractures, altering the rocks through which they migrate.

**IGCC (integrated gasification combined-cycle).** A power-generation process that uses coal gasification to generate syngas (synthesis gas) to fuel gas turbines for electricity generation. Waste heat from the gasification and combustion processes are also captured to make steam that is then used to generate electricity from steam turbines. IGCC plants are more efficient than conventional coal-combustion plants, and result in lower levels of emissions. The gasification process produces a nearly pure stream of CO<sub>2</sub>, which can be easily captured for storage.

**Immiscible.** Phases of fluids or gases that will not mix. Relative to carbon storage, immiscible conditions occur when pressures and temperatures are too low (and depths are too shallow) for CO<sub>2</sub> to mix with subsurface fluids (salt water, oil) or natural gas, so that any injected CO<sub>2</sub> would remain as a separate phase in the reservoir. Shallow, immiscible enhanced-recovery projects are expected to rely primarily on displacement of hydrocarbons in the reservoir.

**Injection fall-off test.** A downhole test used to measure the injectivity of a formation. During an injection fall-off test, gas or fluids are injected into a formation through tubing at a steady rate and pressure. The well is then shut-in, and the pressure of the reservoir is monitored over time with gauges. The rate at which pressure returns to pre-test conditions is a function of the permeability and volume of the reservoir.

**Injectivity.** In petroleum geology and carbon sequestration, a measure of a reservoir's ability to have gas or liquid injected into it.

**Intercrystalline porosity.** Microscopic porosity formed between crystals in rock cements. Typically formed in carbonate rocks as a result of diagenesis.

**Isopach (map).** A thickness map in which lines connect points of equal thickness, similarly to elevation contours on topographic maps.

**Isotope.** One of two or more species of the same chemical element, in which the species have the same

number of protons in a nucleus but different numbers of neutrons. The ratio of isotopes for a given element, such as carbon and oxygen, is sensitive to a wide variety of chemical (e.g., mineral precipitation) and physical (e.g., evaporation) processes, and therefore the isotopes can be used to infer the processes that affected the occurrence and distribution of the element. *Adj. Isotopic.*

**Kaolinite.** An earthy, white to tan clay.

**Karst.** The terrain and features associated with dissolution of soluble bedrock, usually carbonates, that form caves, sinkholes, springs, and other features.

**KGS.** Kentucky Geological Survey. A research branch of the University of Kentucky, which is charged with increasing the knowledge and understanding of the mineral, energy, and water resources, geologic hazards, and geology of Kentucky for the benefit of the commonwealth and nation.

**Kimberlite.** Igneous, ultramafic (dark iron-magnesium minerals), intrusive rock composed of at least 35 percent olivine (a magnesium iron silicate mineral).

**KYCCS.** Kentucky Consortium for Carbon Storage. A State and industry partnership in Kentucky conducting research on carbon sequestration. This partnership is administered by the Kentucky Geological Survey and is separate from the U.S. Department of Energy regional carbon sequestration partnerships. KYCCS maintains a Web site at [www.kyccs.org](http://www.kyccs.org).

**Laminae (laminations).** The thinnest unit layer of deposition in a sedimentary rock. Laminae are less than 1 cm (0.39 in.) thick.

**Limestone.** A sedimentary rock consisting of more than 50 percent calcium carbonate formed from physical or chemical processes.

**Litharenite (lithic arenite).** A sandstone containing more than 25 percent rock (lithic) fragments and having less than 75 percent quartz grains and less than 10 percent feldspar grains.

**Lithology.** The description or physical character of a rock. Generally includes rock type, grain size, bedding, mineral constituents, and cements.

**Mafic.** Term used to describe dark, iron-magnesium minerals in igneous rocks.

**Magnetic data/analyses/anomaly.** Measurements of spatial variations in the earth's magnetic field. Measurements at different surface locations can be used to detect different densities of rock strata in the subsurface. Magnetic *surveys* or *analyses* are done to map variations in the magnetic field. When mapped, *magnetic anomalies* (rapid lateral changes in magnetic measurements) may indicate changes in geology related to mineral-bearing ore bodies or large oil fields.

**Matrix.** The ground mass or finest-grained component of a rock in which framework grains or crystals are embedded. Typically used in carbonate rocks to describe the fine-grained material that surrounds and encompasses larger particles or framework grains.

**Matrix porosity.** Microscopic porosity of the rock matrix, or finer-grained ground mass of a carbonate rock.

**Mcf.** Thousand cubic feet; a standard measure of volume in gas fields. See unit conversion table for equivalents. Mcfg/d would be thousand standard cubic feet of gas per day. In this context, MMcf indicates million standard cubic feet.

**md.** Millidarcy. A standard unit of permeability equal to 1/1,000 of a Darcy. *See Darcy.*

**MGSC.** Midwest Geological Sequestration Consortium. One of seven regional partnerships funded by the U.S. Department of Energy for carbon sequestration research. This partnership is administered through the Illinois State Geological Survey and covers the Illinois Basin, including western Kentucky. The Kentucky Geological Survey is part of the consortium.

**Mica.** A phyllosilicate mineral. Mica is a common constituent of sedimentary rocks, typically appearing as reflective flakes or sheets. *Adj. Micaceous.*

**Micrite.** Very fine-grained crystalline carbonate rock or matrix of carbonate rocks. Typically formed from carbonate muds. *Adj. Micritic.*

**Mineralogy.** The study of the mineral components of a rock. In carbon storage research it is important to know the minerals that compose a reservoir or

confining interval because different minerals will react (or not react) with acids, fluids, and CO<sub>2</sub> at different pressures and temperatures.

**Mineral trapping.** The process in which CO<sub>2</sub> injected into a reservoir dissolves into the formation water (solubility trapping) and forms ionic species, such as bicarbonate, that subsequently react with cations, such as calcium, magnesium, and iron, to form carbonate minerals. Mineral trapping is considered the most permanent form of geologic storage, but it is also one of the slowest.

**Miscible.** Phases of fluids or gases that will mix into a homogenous mixture. Relative to carbon storage, the term is used when pressures and temperatures are high enough (and depths are great enough) for CO<sub>2</sub> to mix with subsurface fluids (salt water, oil) or natural gas in a reservoir.

**Mol or Mole.** The mass (in grams) of a substance that contains  $6.023 \times 10^{23}$  atoms, ions, or molecules, and which is equal to the atomic or formula weight.

**Moldic porosity.** Pores that result from the removal or dissolution of a grain or fossil shell that retain the "mold" or general shape and size of the original grain or shell.

**MRCSP.** Midwest Regional Carbon Sequestration Partnership. One of seven regional partnerships funded by the U.S. Department of Energy for carbon sequestration research. This partnership is administered through Battelle Memorial Institute and covers the mid-Atlantic, northern Appalachians, Michigan Basin, and Arches Provinces, including central and eastern Kentucky. The Kentucky Geological Survey is part of the consortium.

**Mud log.** A graphic representation of the rate a drill is penetrating subsurface rock units while drilling, with notes on rock type from drill cuttings, and other parameters noted during drilling.

**MW (megawatt).** Standard unit in the electrical-power industry equal to 1 million watts.

**Neutron log (neutron porosity log).** A type of geophysical well log that shows a graphic representation of the interactions of fast neutrons (or neutron and gamma rays) emitted from a downhole source with rock and pore fluids. A neutron log principal-



ly measures the effect of hydrogen in pore fluids, so it indirectly measures relative porosity. Most neutron-porosity logs are calibrated for fresh water and rock types, and must be recalibrated (or recalculated) for different rock types. Typically, neutron logs are calibrated to calcite, which means they are scaled to true porosity in limestones, but have to be rescaled for other rock types.

**Normal fault.** A type of fault in which one side of the fault (the hanging wall) has moved down relative to the other side (footwall). The opposite is a reverse fault. Most normal faults are high-angle, or near-vertical in orientation.

**Openhole, open hole.** The (usually) lowermost part of the wellbore in which no protective casing or pipe has been. When used to describe production, it generally means that all intervals below a certain depth to the bottom of the well are not cased. In an injection well, an *openhole completion* would mean injection into the entire uncased interval below a certain depth to the bottom of the well.

**Oolite.** Carbonate rock composed of tiny, rounded, accretionary (gradually increasing in size) particles or grains. The grains are called ooliths. *Adj. Oolitic.*

**Organic content.** A measure of the amount of organic carbon in a material. Organic content is significant in carbon sequestration because high organic contents in some rocks can cause adsorption of carbon dioxide.

**Organic rich.** Used to describe a rock that contains large amounts of solid organic carbon components. Organic content is significant in carbon sequestration because high organic contents in some rocks can cause adsorption of carbon dioxide.

**Packer.** In drilling, a device that can be expanded downhole in the wellbore or casing to seal off intervals of the well for testing, cementing, or casing. When two packers are used to isolate a zone, they are sometimes referred to as *straddle packers*.

**Paleokarst.** Ancient karst. Surface or interval in rock with evidence of ancient karst, including dissolution, sinkholes, conduits, formed from ancient exposure of a carbonate surface and ancient weathering and erosion of that surface or intervals beneath that surface.

**Paleotopography.** Related to an ancient land surface that was buried. The term implies an uneven surface with buried hills and valleys generally along an unconformity. *Adj. Paleotopographic.*

**Paleotopographic high.** A structural high on a paleotopographic surface, such as an unconformity surface. A buried hill. In some cases, paleotopographic highs or lows may preferentially have porosity or permeability and trap oil, gas, or water. Areas of preferential permeability development may have carbon storage potential. A *paleotopographic low* would be a buried valley or depression.

**Peak ground acceleration.** A measure of the maximum acceleration (change in velocity) of a particle during the course of an earthquake motion. Essentially a measure of the maximum amount of shaking that is likely during an earthquake. The U.S. Geological Survey maps peak ground acceleration in earthquake-prone areas for earthquake hazard analysis.

**Perforate, perforated interval.** After production casing or tubing is placed in a wellbore, the casing is shot with holes that penetrate the casing. The holes allow oil or gas from the producing formation to enter the casing and be pumped to the surface in a production well. In an injection well, perforations allow fluid or gas to be injected into a specific rock reservoir, or specific part of a rock reservoir, from the wellbore.

**Permeability.** A measure of the degree to which fluids can move through a rock; in other words, the connectivity of pores and fractures. Permeability is generally measured in darcies or millidarcies (md).

**Petrography.** A measure within a rock unit. The study of the mineral and textural relationships of rocks using microscopy and other techniques. *Adj. Petrographic.*

**pH.** The measure of hydrogen ion activity in solution and is equal to the negative logarithm (base 10) of the hydrogen ion concentration. It is a measure of a solution's acidity.

**Physical trapping.** The process in which CO<sub>2</sub> as a buoyant free-phase is trapped below low-permeability seal rocks in a closed trap—called “structural and stratigraphic trapping”—or in which no

closed trap exists and CO<sub>2</sub> slowly migrates in a saline aquifer over long distances—called “hydrodynamic trapping.” In the latter case, CO<sub>2</sub> is eventually trapped over time by residual, structural, or mineral trapping processes.

**Porosity.** The ratio of the relative amount of open or void space in a rock to the total volume of the rock.

**ppm.** Acronym for parts per million, which is a standard unit in which concentration of ions of dissolved constituents are reported in a weight-per-weight basis as a dimensionless ratio. As a practical matter, ppm is equivalent to milligrams per liter.

**Primary porosity.** Porosity remaining from the original deposition of a sediment. *See also porosity and secondary porosity.*

**Pseudomatrix.** Term used to describe very fine-grained (pasty), interstitial, or intergranular (between grain) material, which looks like a matrix but is discontinuous or different from the matrix. Pseudomatrix typically is formed through the deformation or dissolution of weak detrital grains.

**psi.** Acronym for pounds per square inch, a standard unit of pressure.

**Quartzarenite.** A type of sandstone composed of more than 95 percent quartz grains.

**Quartzose.** Quartz-rich rock. For sandstones, used as a general term for a rock that is either a quartzarenite or a quartz-rich litharenite.

**Reservoir.** A porous and permeable rock body in the subsurface containing quantities of oil, gas, or water and generally isolated to a specific interval by surrounding less-permeable rock, forming confining layers or traps.

**Residual trapping.** The process in which CO<sub>2</sub> fills very small pore spaces between and within grains making up the rock, which renders the CO<sub>2</sub> immobile.

**Resistivity log.** A type of geophysical well log that measures the electrical resistivity of subsurface rocks and interstitial pore fluids. It is useful for delineating hydrocarbons in pore spaces of rock because water conducts electricity but oil and gas

do not. Part of a standard electric log along with spontaneous potential.

**Reverse fault.** A type of fault in which one side of the fault (the hanging wall) has moved up relative to the other side (footwall). The opposite is a normal fault.

**Rhyolite.** A silica-rich, extrusive igneous rock; a felsic igneous rock. In Kentucky, rhyolites are known from subsurface Precambrian strata.

**Rift.** A tensional feature formed when blocks of the earth’s crust pull apart. Typically forms a large graben bounded by faults.

**Salinity.** Equals the total amount of solids (milligrams per liter or parts per million) remaining in a water sample that is evaporated to dryness.

**Saline aquifer.** A subsurface reservoir containing highly saline water (typically more than 10,000 ppm of dissolved salts). In carbon sequestration research, the term is typically used to denote regionally widespread, saltwater-bearing units, compared to more local oil and gas reservoirs, which may also contain salt water, but only in small areas.

**Saline water.** Water that contains a significant concentration of dissolved salts. Freshwater salinity equals 1,000 ppm or less of total dissolved solids and seawater salinity averages 35,000 ppm of total dissolved solids. Brines have salinities significantly greater than seawater. For purposes of underground injection, it is critical to know the depths of fresh, potable water and the salinity of deeper waters in potential storage reservoirs.

**Sandstone.** A sedimentary rock composed of sand-size grains. Sand grains are often naturally cemented together. Porous and permeable sandstones are common reservoir rocks. The thickness, lateral extent, mineralogy, porosity, permeability, and homogeneity are some of the factors that influence its potential for carbon storage.

**Seal.** An impermeable rock layer that does not allow vertical or lateral migration of fluids or gas from underlying or adjacent reservoirs. Adequate seals must be demonstrated to regulatory agencies for permitting an underground injection well. A *confining layer*.

**Sealing fault.** Faults are termed sealing when fluids and gases are confined within a reservoir by the faults. Sealing faults form *structural traps* in *reservoirs*. When faults are conduits for fluid or gas migration they are termed *transmissive faults*.

**SECARB.** Southeast Regional Carbon Sequestration Partnership. One of seven regional partnerships funded by the U.S. Department of Energy for carbon sequestration research. This partnership is administered through the Southern States Energy Board and covers the southeastern United States, including the southeastern part of the Eastern Kentucky Coal Field.

**Secondary porosity.** Porosity that develops after deposition, typically through fluid migration and dissolution, fracturing, etc. *See also porosity and primary porosity.*

**Secondary recovery.** The second stage of oil or gas recovery. The first stage is natural flow due to gravity or pressure from the reservoir to the wellbore. When that motive force decreases, an external fluid or gas is injected into the reservoir through selected wells in order to increase or maintain pressure in the reservoir and push or displace *hydrocarbons* to a producing well. *Waterfloods* are the most common type of secondary recovery, but there are many different methods. In contrast to secondary recovery, where the goal is repressurization, *enhanced oil and gas recovery*, or *tertiary recovery*, involves methods that alter the chemical or physical composition of the residual oil or gas in the reservoir.

**Sedimentary basin.** A broad low area in the earth's crust in which sediments accumulated and lithified to form sedimentary rocks.

**Shale.** A lithified, fine-grained sedimentary mudstone composed of clay- and silt-size particles. Shales, in contrast to mudstones, have a finely laminated structure, called *fissility*, along which the rock breaks readily. Shales typically have low porosity and permeability, and, where thick, often form good confining intervals or natural seals.

**Show of oil or gas.** In drilling, an indication of oil or natural gas in a wellbore. A show is typically determined at the surface from fluorescence in cut-

tings when they come to the surface or increased gas readings on gas detection equipment.

**Shut-in well.** A well that could produce hydrocarbons (oil or natural gas) that is temporarily sealed or shut off for some economic or technical reason.

**Sidewall core.** A core taken from the side of a wellbore. These cores can be taken after a well has been drilled, as opposed to full (whole or conventional) core, which is taken during drilling. Sidewall cores, however, are much smaller than whole (conventional) core, generally 1 in. or less in diameter and 1 to 2 in. long. Cores provide actual samples of rock strata for reservoir testing and analyses.

**Siltstone.** A sedimentary rock composed of silt-size grains.

**Seismic data/surveys/analyses.** Measurements of elastic waves of energy (typically transmitted by P and S waves) used to interpret the composition, fluid content, and layering of rock units in the subsurface. Typically, a seismic wave is generated at a source on the surface and then a series of monitoring devices measure the reflection of the energy as it reflects off of subsurface rock units. The data are then processed to produce a seismic cross section of the subsurface rock layers. Seismic surveys have been required for all of the DOE-sponsored carbon dioxide injection test wells in order to determine if there were any faults or structures within the area of influence that could negatively influence containment of the injected carbon dioxide.

**Seismic risk/hazard analysis.** Method for examining the potential consequences or probabilities of earthquakes in an area. Seismic risks are determined based on past occurrences of earthquakes in an area and computer modeling of the likely manner in which bedrock and sediment will propagate seismic energy in an earthquake. Seismic-risk analysis is required for most federal building and construction projects, and may be needed for large-scale underground injection projects. The U.S. Geological Survey has published seismic-risk maps for the entire United States.

**Skeletal grains.** Grains in carbonate rocks formed from the calcite or aragonite skeletons of marine plants and organisms. For example, shell fragments are common skeletal grains.

**Solubility.** The extent to which one substance will dissolve into another. For carbon storage, the focus is on the degree to which CO<sub>2</sub> will dissolve into formation waters.

**Solubility trapping.** The process in which CO<sub>2</sub> dissolves into formation waters. The extent of dissolution generally decreases with increasing temperature and salinity, and increases with increasing pressure. The process removes CO<sub>2</sub> as a separate buoyant phase.

**Solution features.** Any physical feature formed from the solution of soluble rocks, such as limestone, by acidic water. Features include any of a number of karst features such as conduits, caves, sinkholes, etc.

**Sorting (sandstone).** Fabric of sedimentary rocks, typically applied to sandstones, which describes the general distribution of grain sizes in the rock based on standard deviations. Very well sorted means 0.35 to 0.50 standard deviations, which means that most of the grains in the rock have similar size. Poorly sorted means 1.4 to 2.0 standard deviations, which means there is a wide distribution in grain sizes. Well-sorted sandstones typically have better porosity than poorly sorted sandstones because small grains fill the poor spaces between larger grains in poorly sorted sandstones (although other factors also influence porosity).

**Source rock.** A rock unit with a high organic content that if heated could or has generated hydrocarbons. Hydrocarbons then migrate to reservoirs. Most source rocks are organic-rich shales, typically containing at least 1 percent organic matter and at least 0.5 percent total organic carbon. In Kentucky, for example, the Devonian black shales (Chattanooga Shale, Ohio Shale, New Albany Shale) are known source rocks.

**Spontaneous potential (SP) log.** A type of geophysical well log that measures the electrical potential of subsurface rocks and interstitial pore fluids from wireline tools lowered down the wellbore. This log is useful for detecting permeability in subsurface rock layers because it detects differences in salinity between drilling muds and formation fluids. It is also useful for determining clay content of beds. It is part of a standard electric log, along with resistivity.

**Standard deviation.** A measure of the spread of values from their average.

**Stimulation.** A well treatment used to restore or enhance productivity in a well, or enhance the permeability or hydraulic connectivity between the reservoir and the wellbore.

**Straddle packers.** *See packers.*

**Stratigraphy.** The study and correlation of rock units to determine their relative stacking, distribution, depositional origins, and ages. *Adj. Stratigraphic.*

**Stratigraphic trap.** A trap or seal on a *reservoir* in which changes in rock types, layering, or bedding form the *seal* or *trap*.

**Strike-slip fault.** A type of fault in which the rock blocks on either side of the fault slide past each other, rather than up or down relative to the other block. Informally termed a tear fault.

**Structure.** A geologic feature formed from deformation of the earth's crust, such as a fault or fold. *See also structure map. Adj. Structural.*

**Structural closure.** Term used to indicate a closed structural contour on a structure map, generally denoting a structural high in a reservoir, which may form a *structural trap*.

**Structural relief.** The relative difference in depth from the top of a surface to the base of a surface (for example, the top surface of a rock unit) at depth across some structure, *paleotopographic* feature, or trap, generally referring to an irregular *unconformity* surface or a reservoir.

**Structural trap.** A *trap* or *seal* on a *reservoir* in which the reservoir is sealed along a fault or through the dip or attitude of beds in a structure such as an *anticline* or *syncline*.

**Structure map.** A subsurface map of a surface, such as the top or bottom of a rock unit or reservoir. Contour lines on the map represent points of equal elevation, generally drawn relative to a sea-level datum, although other datums may be used. Hence, they are similar to a topographic map of a subsurface unit. Structure maps are useful for determining the dip of rock strata and the occurrence of structural features such as anticlines and synclines.

- Subcrop.** Point or line at the surface where a subsurface rock unit comes to the surface of bedrock. The rock unit may be covered by modern alluvium and soil, and not actually exposed or *cropping out*.
- Sublitharenite.** A type of sandstone between lithic arenite (litharenite) and quartzarenite. Composed of 75 to 95 percent quartz and 5 to 25 percent rock (lithic) fragments.
- Subsea.** Below sea level. The term is generally used to denote elevation below sea level on structure maps and cross sections.
- Supercritical (fluid).** Refers to a substance that exceeds its critical point (critical temperature and pressure) with near-liquid density and a viscosity similar to the gas phase. For CO<sub>2</sub>, the critical point is 1,085 psi at 88°F (74.8 bar at 31.1°C), which occurs at depths of approximately 2,500 ft in most of Kentucky. For industrial-scale geologic sequestration, keeping CO<sub>2</sub> at supercritical conditions in underground reservoirs will be important, because there is a significant (approximately 250 times) volume reduction of supercritical CO<sub>2</sub> relative to gaseous CO<sub>2</sub>.
- Syncline.** A local geologic structure in which rock units are folded (downwarped), such that the elevation of a rock unit along the axis of the structure is less than the elevation of the rock unit on either flank. These structures are smaller scale than regional basins. The opposite type of structure is an *anticline*.
- Synsedimentary.** Occurring when the sediment that formed the sedimentary rock was deposited.
- TD.** Acronym for total depth of a well.
- Total dissolved solids, TDS.** The total dissolved material in a liquid, measured as the materials small enough to pass through a filter or sieve of 2 micrometers. TDS measurements are used for salinity analysis. Deep formation waters are salty and have high TDS values.
- Tertiary recovery.** *See enhanced oil or gas recovery.*
- Thrust fault.** A type of reverse fault in which one fault block has moved or been thrust over or across another fault block. Typically, these are low-angle, sometimes near-horizontal, faults.
- Tight (rock unit).** Adjective used to describe rock units that show little permeability or are well cemented.
- TOC.** Acronym for total organic carbon. A common measure of the amount of organic carbon in a rock unit. It is an important measurement for determining original source rocks and for determining *adsorption* mechanisms relative to the injection of carbon dioxide in the subsurface.
- Ton.** Standard U.S. ton, also called a short ton, equals 2,000 U.S. pounds or 0.907 metric tonne.
- Tonne.** Metric ton, equals 1,000 kilograms or 1.103 U.S. short tons.
- Trachyte.** Igneous, extrusive volcanic rock that is fine-grained and dominated by alkali feldspar and minor mafic (dark) minerals.
- Transmissive (fault).** Faults are termed transmissive when fluids and gases can migrate along the faults or fractures associated with faults. Faults can also be *sealing* and form *traps*.
- Trap.** In oil and gas geology, a rock reservoir capable of holding hydrocarbons and sealed by relatively impermeable rocks through which the hydrocarbons will not migrate. *See also structural trap and stratigraphic trap.*
- Treatment (well treatment).** General term for methods in which fluids are pumped down a well to resolve a wellbore or reservoir condition. *See stimulation.*
- TVD.** Acronym for true vertical depth of an intentionally deviated or horizontal well from the ground surface to the deepest penetration of the wellbore in a vertical plane. The measured depth of the well is the total length of the wellbore. TVD is used with wellbore deviation data to correct observed rock unit thicknesses as penetrated at some angle to the actual bedding to the true vertical thickness of the unit.
- Unconformity.** A rock surface that represents a substantial gap in the geologic record in which rock units below the surface are overlain by rock units that would not be in depositional succession. Typically, it is either an erosive contact or a surface of ancient exposure and weathering. A number of terms apply to different scales of unconformity (and disconformity) related to the scale (or area) of the surface, or the relative geometry of the units

above and below the surface. Oil and gas traps (and porosity development) are common beneath unconformity surfaces.

**Unconsolidated.** In geology, adjective applied to sediments or rocks, to indicate they are uncemented. Drillers sometimes use this as an adjective to describe poorly cemented or uncemented rocks downhole.

**University of Kentucky.** A large public university in Lexington, Ky., known primarily for the success of its basketball team and the Kentucky Geological Survey, one of its research centers.

**Vug.** A large pore or cavity in a rock. Typically an irregularly shaped pore of nonspecific origin. *Adj. Vuggy, vugular.*

**Vuggy porosity.** Porosity formed from vugs. It is typically larger than the grains that comprise the rock, or the crystals in the cement holding the grains together.

**Water-drive reservoirs.** Reservoirs in which the primary recovery mechanism is pressure from natural water in the reservoir, generally at a position below the oil or gas layer.

**Waterflood.** A type of secondary recovery in which water is injected into a reservoir from one or more

injection wells, and used to push or displace residual oil toward a producing well.

**Water saturation.** The fraction of water that occupies the pore space, typically expressed as a percentage.

**Wellbore.** A hole drilled in the ground. Pertaining to the drillhole or the rocks that line the drillhole.

**Wireline (logging).** A method of deploying in a wellbore retrievable tools that are suspended from an electrically conductive cable for the purpose of acquiring continuous measurements of rock and fluid properties. Nuclear logs measure radioactive properties and provide information on density, porosity, fluids, and rock type. Electrical logs measure natural and induced electrical properties and provide information on rock type, porosity, and fluids. Geophysical logs provide measurements of physical properties of rock types (sonic velocities) and porosity. Mechanical logs provide information on variations in borehole diameter, velocity of fluids in the borehole, and other properties. Often the tool as deployed contains multiple sources and sensors of each major type and all are recorded simultaneously for later analysis.