The geology of the Morehead 30 x 60 minute quadrangle was digitally compiled mostly from U.S. Geological Survey 7.5-minute geologic quadrangle maps (GQ's), as cited in the references. The original maps were products of a cooperative mapping project between the U.S. Geological Survey and the Kentucky Geological Survey from 1960 to 1978. The conversion into digital format has been another USGS-KGS cooperative program funded through the National Cooperative Geologic Mapping Program (STATEMAP). Several regional ologic studies (Cressman, 1973; Dever and others, 1977, 1990; McDowell, 1983; Ettensohn and others, 984; Weir and others, 1984; Sable and Dever, 1990; Chesnut, 1992; Drahovzal and Noger, 1995) have resulted in changes to the stratigraphic nomenclature since the original GQ's were completed. Geologic, geophysical, and geochemical data collected by various mining companies since the original maps were published have also contributed new information. These changes have been incorporated into this map and were necessary for updating and compiling regional maps in order to maintain stratigraphic continuity between quadrangles. The 7.5-minute quadrangles that make up the Morehead 30 x 60 minute quadrangle are shown The data files resulting from digitizing the GQ's, referred to as DVGQ's (Digitally Vectorized Geologic Quadrangles), are part of a comprehensive relational and spatial data set being developed by the Kentucky eological Survey (Anderson and others, 1999). Users will have at their disposal spatial data sets from which to select geologic themes to create custom maps, to which they may add supplemental oil, natural gas, mineral, coal, or water information also from the KGS databases. These databases can be used in a geographic information system (GIS) to create and analyze maps or manipulate data. The 7.5-minute GQ's were digitally compiled using a semi-automated data-capture technique to convert hard-copy geologic maps into digital format. Compiling 7.5-minute maps into a 30 x 60 minute map required the resolution of significant problems, such as (1) correlating geologic formations and members across quadrangle boundaries, (2) determining the boundary of newly defined formations resulting from changes stratigraphic nomenclature since the release of the original GQ's, and (3) resolving discrepancies in Quaternary alluvium boundaries and inferred contacts. The metadata portion of the digital file for this map provides detailed sources of data and information about the methods used to resolve these problems. rmation codes were assigned using the American Association of Petroleum Geologists' standard stratigraphic code (Cohee, 1967), modified by KGS for state-specific use. Formations and formation boundaries were no mapped consistently on each of the 7.5-minute GQ's as they were compiled between 1960 and 1978. Resolution of the differences between quadrangles was necessary for topological analysis in a GIS environment. These issues were resolved by adhering to geologic, cartographic, and GIS standards using the best current This map is a compilation of existing maps and published information, and no additional field work was **GEOLOGIC SETTING** The Morehead 30 x 60 minute quadrangle lies on the eastern flank of the Cincinnati Arch, along the edge of the Appalachian Basin, and on the northern platform of the Rome Trough, a Cambrian rift basin. The Rome Trough is a linear asymmetric Precambrian graben that dominates the basement surface configuration in eastern Kentucky. It was first noted by Thomas (1960), and described by Woodward (1961), who recognized the abrupt southeastward thickening of Cambrian sediments in the subsurface. This trough extends eastward across the state beginning at the Grenville Front in central Kentucky, and is part of a larger Cambrian extensional feature that extends northeastward across West Virginia, Pennsylvania, and into southern New York. The trough represents a late Precambrian to Cambrian continental rift zone formed contemporaneously with Cambrian lapetan rifting (mid-ocean-ridge spreading) (Ammerman and Keller, 1979; Thomas, 1991). The elevation of the top of the Precambrian Grenville basement rocks in the southeastern corner of the quadrangle is approximately 5,000 to 10,000 ft below sea level (see cross section). The east-trending Kentucky River Fault System is in the basement rocks in the southern part of the quadrangle. It represents the northern boundary of the Rome Trough (McGuire and Howell, 1963; Drahovzal Another structure that influenced the geology of the Morehead 30 x 60 minute quadrangle is the Waverly Arch (not shown). This arch is a north–south-oriented structure defined from evidence of depositional and erosional thinning of early Paleozoic formations (Woodward, 1961). The low, broad arch extends from northern Ohio southward into the northeastern part of the Morehead quadrangle. Reactivation occurred in the Late Mississippian and continued intermittently into the Pennsylvanian. The depositional environments and sedimentary structures associated with the re-emergence of the arch are presented in Dever and others During the Paleozoic, there were several episodes of fault reactivation and subsidence in the area, resulting in deposition and thickening of Cambrian and lower Paleozoic sediments in the Rome Trough (McGuire and Howell, 1963; Harris and Drahovzal, 1996; Harris and others, 2004), as well as local influence on the deposition and erosion of the Mississippian Slade (Newman) Formation (Dever and others, 1977, 1990). The sedimentary rocks in the Morehead area consist of gently dipping Upper Ordovician limestones and shales in the western part of the quadrangle; Silurian, Devonian, and Mississippian rocks in the central part; and Pennsylvanian rocks in the eastern and southeastern parts (see Figure 2). The Upper Ordovician rocks are primarily interbedded limestone and shale with minor siltstone. The Silurian are mainly dolomite and Harris, D.C., and Baranoski, M.T., 1997, Cambrian pre-Knox group play in the Appalachian Basin: shale. The Devonian consists of dolomite and shale including, the massive carbonaceous black shale. A Harris, D.C., and Drahovzal, J.A., 1996, Cambrian hydrocarbon potential indicated in Kentucky's Rome Trough: Kentucky Geological Survey, ser. 11, Information Circular 54, 11 p. major regional unconformity occurs at the base of the Devonian black shales called the Ohio and New Albany Shales. The Mississippian rocks include limestone, dolomite, and the siltstone, shale, and sandstone detrital Harris, D.C., Drahovzal, J.A., Hickman, J.G., Baranoski, M.T., and Avary, K.L., 2004, Rome Troug final report and data distribution: Kentucky Geological Survey Open-File Report OF-04-06, units of the clastic deltaic wedge that forms the Borden Formation. Many karst features have formed in the limestones of the Mississippian Slade Formation in the northeastern part of the quadrangle near Carter Caves State Resort Park. Another major regional unconformity occurs at the base of the Mississippian section. The Humphreys, M., and Watson, A.E., 1997, Middle Ordovician St. Peter Sandstone gas play in the Pennsylvanian rocks consist of sandstones, shales, several coals beds, and clay beds, including the Olive Hill Clay Bed. Many of the Pennsylvanian sandstones are associated with channel fills along a northeast-Jillson, W.R., 1924, Glaciation in eastern Kentucky: Pan American Geologist, v. 42, p. 125–132. Jillson, W.R., 1927, The topography of Kentucky: Kentucky Geological Survey, ser. 6, v. 30, 60 p. trending corridor in the eastern part of the quadrangle. Krieger, R.A., Cushman, R.V., and Thomas N.O., 1969, Water in Kentucky: Kentucky Geological Survey, ser. 10, Special Publication 16, 51 p. In 1902, a large meteorite fell near Salt Lick in Bath County and was observed by several people (Ehmann, Lambert, J.R., and Sparks, T.N., 2005, Spatial database of the Wesleyville quadrangle, northea 2000). The largest piece of the meteorite, classified as a chondrite, weighed 178 lb and is located at the Field ntucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Da GQ-1305. Adapted from Philley, J.C., and Chaplin, J.R., 1976, Geologic map of the Wesleyv Museum of Natural History in Chicago. quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1305, scale 1:24,000. Several rocks have been found in the guadrangle that were not derived from the bedrock of Kentucky, but Leverett, F., 1929, The Pleistocene of northern Kentucky: Kentucky Geological Survey, ser. 6, v. 31, were transported into the quadrangle by glacial processes during the Pleistocene ice advances. These erratics probably originated in Canada. In the Burtonville 7.5-minute quadrangle, the remains of a large erratic known as the Epworth boulder are strewn on the hillside along the north side of Beechy Creek. The rock is a porphyritic granite, gneiss, compose of large crystals of pink orthoclase in a coarsely crystalline groundmass of quartz, feldspar, and mica Pointdexter, 1924). It was estimated to have weighed approximately 16 tons, but was blasted into hundreds volcanic-ash deposit (tonstein): Geological Society of America Bulletin, v. 104, p. 1515–15 of small pieces, which are scattered about the ground. A large metamorphic rock known as the Farmers boulder is located in the Farmers 7.5-minute quadrangle. McDowell, R.C., 1983, Stratigraphy of the Silurian outcrop belt on the east side of the Cincinnati Arch in Kentucky, with revisions in the nomenclature: U.S. Geological Survey Professional Paper The rock was photographed and described by Leverett (1929), who called it a schistose quartzite. It is a medium gray quartzose phyllite, and measures approximately 10 ft long by 2 to 3 ft across. McFarlan, A.C., 1943, Geology of Kentucky: Lexington, University of Kentucky, 531 p. McGrain, P., and Kendall, T.A., 1972, Miscellaneous analyses of Kentucky clays and shales for 1960–1970: Kentucky Geological Survey, ser. 10, Report of Investigations 12, 62 p. A gneissic granite cobble was found in the Stricklett 7.5-minute quadrangle. The fragment measures 4 by 4 by 3 in.; quartz, hornblende, and pink feldspar are recognizable (Jillson, 1924, 1927). The cobble has been McGrain, P., and Noger, M.C., 1982, Economic geology of Rowan County, Kentucky: Kentucky Geological Survey, ser. 11, County Report 2, 34 p. donated to the University of Kentucky Geological Museum. An ovoid boulder of coarse-grained biotite granite, approximately 1 ft in length and 10 in. in diameter, was McGuire, W.H., and Howell, P., 1963, Oil and gas possibilities of the Cambrian and Lower Ordovician in Kentucky: Lexington, Ky., Spindletop Research, various pagination. found in the Plummers Landing 7.5-minute quadrangle. The recent discovery of a large granite boulder imbedded within the Sunbury Shale in Rowan County has brought to light the possibility of Lower Mississippian glaciation (Lierman and Mason, 2006). The ice-rafted Miller, A.M., 1919, The geology of Kentucky: A classified compendium of state reports and other publications with critical comment based or original investigations: Kentucky Geological Survey, ser. 5, Bulletin 2, 392 p. "dropstone" is a low-grade metamorphically altered biotite granite boulder measuring 5.6 x 4.3 x 2.5 ft and weighing approximately 3 1/2 tons. Lierman and Mason (2006) suggested that the unweathered boulder was rafted by an iceberg from the Gondwana ice sheet during the Early Mississippian. Moody, J.R., Kemper, J.R., Johnston, I.M., Elkin, R.R., Smath, R.A., and Frankie, W.T., 1988, The ECONOMIC GEOLOGY geology and the drilling and production history of the Upper Devonian shale of northeastern (entucky (Boyd, Carter, Elliott, Greenup, Lawrence, Lewis, Menifee, Morgan, and Rowan Counties): Kentucky Geological Survey report for the Gas Research Institute, Contract 5084-Industrial Minerals The primary economic products in the quadrangle are limestone, clay, oil and gas, and some minor coal. Moore, B.R., and Clarke, M.K., 1970, The significance of a turbidite sequence in the Borden Formation Iron mining was a major industry in Bath County from the 1800's to a peak in the early 1900's; several furnaces (Mississippian) of eastern Kentucky and southern Ohio, *in* Lajoie, J., ed., Flysch sedimentology in North America: Geologic Association of Canada Special Paper 7, p. 211–218. were constructed (Miller, 1919; McFarlan, 1943; Anderson, 1994). The iron was smelted from oolitic hematite in Silurian and Devonian carbonate rocks. There is no active iron mining in the quadrangle. Murphy, M.L., 2005a, Spatial database of the Grahn quadrangle, Carter County, Kentucky: Kentucky eological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-1262. Adapted om Englund, K.J., 1976, Geologic map of the Grahn quadrangle, Carter County, Kentucky: S. Geological Survey Geologic Quadrangle Map GQ-1262, scale 1:24,000. Sandstone has been quarried for local use; there are silica sand deposits in the quadrangle (Anderson and Dever. 2001), but they are not currently active. In 2001, limestone suitable for construction aggregate and agricultural products was mined from Ordovician Murphy, M.L., 2005b, Spatial database of the Head of Grassy quadrangle, Lewis County, Kentucky Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGC and Mississippian limestones from seven quarries in Morgan, Carter, and Fleming Counties. The estimated 484. Adapted from Morris, R.H., 1966, Geologic map of the Head of Grassy quadrangle, Lewis County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-484, scale 1:24,000. annual production from all quarries was approximately 3 million tons. Clay has been an important resource in the eastern part of this quadrangle, and has been mined for more Murphy, M.L., 2005c, Spatial database of the Hillsboro quadrangle, Fleming and Bath Counties, than 100 years (McGrain and Kendall, 1972). The Olive Hill Clay Bed is both a high-temperature refractory flint clay and a low-temperature semi-flint clay. The flint clay is kaolinitic, whereas the semi-flint and plastic quadrangle, Fleming and Bath Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-876, scale 1:24,000. clays contain less kaolin and more illitic and mixed-layer clays. The refractory clays are used for a variety of clay products, including ceramic raw materials and firebrick. Low-refractory clays are used for structural Murphy, M.L., 2005d, Spatial database of the Isonville quadrangle, eastern Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-501. Adapted from Englund, K.J., and DeLaney, A.O., 1966, Geologic map of the Isonville quadrangle, eastern clay products such as sewer and drain tile, and common brick. The Olive Hill Clay Bed occurs near the base of the Pennsylvanian Grundy Formation, from the Bangor 7.5-minute guadrangle in the southwest to the Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-501, scale 1:24,000. ygarts Valley 7.5-minute quadrangle in the northeast. Its original resources were estimated at over 150 , M.L., 2005e, Spatial database of the Plummers Landing quadrangle, Fleming and Ro million tons, but most of the high-grade clay has since been mined (Patterson and Hosterman, 1960, 1962). Numerous coal beds occur in the quadrangle, but most are less than 14 in. thick and are considered map of the Plummers Landing quadrangle, Fleming and Rowan Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-964, scale 1:24,000. uneconomic. The lower Broas (not mapped), Mudseam (Peach Orchard coal zone), and Cannel City (Williamson and Amburgy) coal beds are locally greater than 28 in. thick in southeastern Elliott County (Brant, 1983), and Murphy, M.L., 2005f, Spatial database of the Preston quadrangle, Bath and Montgomery Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-1334. Adapted from Weir, G.W., and McDowell, R.C., 1976, Geologic map of the Preston some have been mined. The total amount of coal mined from the quadrangle is approximately 30 million ons; peak production was from the late 1970's through the 1980's. According to the Kentucky Office of Mine quadrangle, Bath and Montgomery Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1334, scale 1:24,000. Safety and Licensing, essentially no coal has been mined in this quadrangle since 1993. Murphy, M.L., 2005g, Spatial database of the Sandy Hook quadrangle, Elliott and Morgan Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-521. Adapted from Englund, K.J., and DeLaney, A.O., 1966, Geologic map of the Sandy Hook quadrangle, Elliott and Morgan Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle, Map GQ-521, scale 1:24,000 Oil and natural gas have been produced in the quadrangle since the early 1900's (McGrain and Noger, 1982). More than 1,500 exploratory wells have been drilled in this quadrangle; approximately 200 have shown natural gas and approximately 500 have shown oil, according to records at the Kentucky Geological Survey. Quadrangle Map GQ-521, scale 1:24,000. Oil and natural gas production comes from the stratigraphic section commonly referred to as the "Corniferous" Murphy, M.L., 2005h, Spatial database of the Soldier quadrangle, northeastern Kentucky: Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-1233. Adapted from Philley, J.C., Hylbert, D.K., and Hoge, H.P., 1975, Geologic map of the Soldier quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1233, scale (a drillers' term), which includes the Silurian Bisher, Salina, and Lockport Dolomites. Production from the Ragland, Bluestone, and North Triplett Fields in Rowan County occurs in the Corniferous along a northeast linear trend where the Corniferous strata are truncated by a major regional angular unconformity at the base of the Devonian black shales (Meglen and Noger, 1996). Additional oil has been discovered in the Isonville and Homer Fields in Elliott County. Natural gas production n the Homer Field is from the Cambrian Rome sands at a depth of approximately 7,500 ft in the Rome Geological Survey Geologic Quadrangle Map GQ-394, scale 1:24,000. Frough. Other producing strata in the quadrangle include Pennsylvanian sandstones, the Mississippian Weir sands, the Devonian Ohio and New Albany Shales, the Ordovician High Bridge Group and St. Peter Sandstone, Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-170. Adapted Hosterman, J.W., Patterson, S.H., and Huddle, J.W., 1961, Geology of the Wrigley quadr Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-170, scale 1:24,000. and the Cambrian-Ordovician Knox Dolomite (McGuire and Howell, 1963; Moody and others, 1988; Harris and Baranoski, 1997; Humphreys and Watson, 1997). lurphy, M.L., and Petersen, C., 2005a, Spatial database of the Cranston quadrangle, northeaster According to the Kentucky Office of Mine Safety and Licensing-Division of Oil and Gas, oil production records go back to 1923. Through the mid to late 1920's production averaged approximately 10,000 barrels the Cranston quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1212, scale 1:24,000. per year. Production peaked in 1957 at 110,000 barrels. Through the 1990's production averaged approximately 19,000 barrels per year, and in 2003, the latest year for which data are available, production was 13,600 barrels. Cumulative oil production in the quadrangle is estimated to be 4 million barrels, primarily from the Rowan County fields. Significant commercial quantities of natural gas began to be produced in 1994 from the Homer Field, and by 2003 the field had produced approximately 2.8 billion cubic feet of natural gas. The primary geologic hazards in the quadrangle are soluble limestone and unstable shales. The natural dissolution of limestone bedrock creates a terrane known as karst. In this guadrangle, karst terrane develops in Ordovician and Mississippian limestones and produces sinkholes, underground streams, and caves. Carter .L., Jr., 2005, Spatial database of the Sharpsburg quadrangle, east-central Kenti Caves State Resort Park in Carter County contains an extensive network of caves and underground streams. Landslides and slope instability have occurred in areas of steep slope, especially in the shale units of the Upper Ordovician Kope Formation and Crab Orchard Group. Also susceptible are the Devonian New Albany Nelson, H.L., Jr., and Petersen, C., 2005a, Spatial database of the Colfax quadrangle, east-central and Ohio Shales, as well as the shale and siltstone units of the Mississippian Borden Formation. cky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data Q-1332. Adapted from McDowell, R.C., 1976, Geologic map of the Colfax quadrangle, central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1332, scale Radon contamination is a potential problem in structures built on the Mississippian or Devonian black shales (Sunbury, Ohio, and New Albany Shales) or localized residual clay beds and phosphate residuum in the Lexington Limestone. Structural damage to foundations can occur in black shale areas that have an abundance Nelson, H.L., Jr., and Petersen, C., 2005b, Spatial database of the Haldeman quadrangle, Kentucky: of pyritic minerals. Expansion, especially in newly exposed shale, occurs when dissolution and oxidation cucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-Adapted from Patterson, S.H., and Hosterman, J.W., 1961, Geology of the Haldeman drangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-169, scale convert these minerals to sulfates such as gypsum. Swelling caused by mineral growth results in the shales heaving. Adequate drainage can mitigate these problems. Because these organic-rich shales are a majo source of natural gas, seepage of this gas into foundation structures is another item for concern (John D. H.L., Jr., and Petersen, C., 2005c, Spatial database of the Olive Hill quadrangle, northeastern Kiefer, Kentucky Geological Survey, personal communication, 2005). Earthquakes are also a hazard. The area near Sharpsburg, Bath County, was the site of a magnitude 5.2 earthquake on July 27, 1980. This was the first recorded earthquake in the area, and caused millions of dollars worth of damage to area homes and businesses. Nelson, H.L., Jr., and Petersen, C., 2005d, Spatial database of the Owingsville quadrangle, Bath and The Maxey Flats Disposal Site is a low-level radioactive waste-disposal site located on a southern promontory of Maxey Flats ridge in the southeastern corner of the Plummers Landing 7.5-minute quadrangle. The site encompasses approximately 280 acres owned and maintained by the Commonwealth of Kentucky. Burial of radioactive waste at Maxey Flats began in May 1963. As of January 1972, more than 1.2 million curies of byproduct material (material made radioactive by exposure to radiation), 460 lb of special nuclear material including plutonium and uranium, and 87,000 lb of source material including uranium and thorium had been Palmgreen, K.A., 2005a, Spatial database of the Ault quadrangle, northeastern Kentucky: Kentucky eological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-1066. Adapted om DeLaney, A.O., and Englund, K.J., 1973, Geologic map of the Ault quadrangle, northeastern entucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1066, scale 1:24,000. buried there. Liquid wastes, primarily tritiated water, were accepted from 1963 to 1972. All commercial disposal operations at Maxey Flats were terminated in 1977. Exposed rocks are of Mississippian and Late Devonian age, and include, in descending order, the Nancy Palmgreen, K.A., 2005b, Spatial database of the Moorefield quadrangle, northeastern Kentucky Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGC 1510. Adapted from Wigley, P.B., 1978, Geologic map of the Moorefield quadrangle, northeaster Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1510, scale 1:24,000. and Farmers Members of the Borden Formation; the Sunbury, Bedford, and Ohio Shales; and the upper part of the Estill Shale of the Crab Orchard Group. All radioactive waste was buried in the shale of the Nancy gure 2. Location map for structure contours in the Morehead 30 x 60 minute guadrar Palmgreen, K.A., and Murphy, M.L., 2005, Spatial database of the Sherburne quadrangle, northeastern peologic map as thin red dashed lines. Contour interval is 40 ft with index contours ever Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-854. Adapted from Outerbridge, W.F., 1970, Geologic map of the Sherburne quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-854, scale Waste was stored in trenches, which were constructed by excavating soil and rock. After the radioactive wastes were placed in the trench, soil removed during the excavation was backfilled over the trench, which was then capped with 3 to 10 ft of crushed shale and compacted clay. Trench caps were then graded, contoured, and seeded to promote drainage away from the trench (Zehner, 1983). Palmgreen, K.A., and Petersen, C., 2005, Spatial database of the Bangor quadrangle, east-central Between 1971 and 1983, radiation levels above background were detected outside the trench areas. Source Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-947. Adapted from Hylbert, D.K., and Philley, J.C., 1971, Geologic map of the Bangor materials for these higher radiation levels included tritium and other radionuclides, suggesting that the trenches quadrangle, east-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-94 scale 1:24 000 had been breached. The Maxey Flats site was placed on the U.S. Environmental Protection Agency's Madison Falmouth Maysville Ironton Superfund National Priority List in 1986. In 1996, Initial Remediation Phase operations began, and the Patterson, S.H., and Hosterman, J.W., 1960, Geology of the clay deposits in the Olive Hill District, Certification of Completion for the Initial Remediation Phase was issued by the EPA in October 2003. Kentucky: Kentucky Geological Survey, ser. 10, Reprint 5, 23 p. Patterson, S.H., and Hosterman, J.W., 1962, Geology and refractory clay deposits of the Haldeman and Wrigley quadrangles, Kentucky: U.S. Geological Survey Bulletin 1122-F, 92 p. Jasper | Louisville |Lexington <mark>Mo</mark> Petersen, C., 2005, Spatial database of the Cowan quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-1466. Adapted from Blade, L.V., 1978, Geologic map of the Cowan quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1466, scale 1:24,000. Water resources and availability for the quadrangle are plentiful (Krieger and others, 1969). Many of the West Evansville Tell City Elizabeth- Harrods- burg Irvine larger cities have public water supply, but most of the rural areas rely on wells or springs for domestic sources of water. Wells located along the Licking River and other major tributaries in the quadrangle will produce enough water for a domestic supply, except during dry weather. In many upland areas, most drilled wells will Plauché, S.T., 2005, Spatial database of the Bruin quadrangle, Elliott and Carter Counties, Kentucky not produce enough water for a dependable domestic supply, unless they are drilled in valley bottoms or ntucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGC 2. Adapted from Englund, K.J., and DeLaney, A.O., 1966, Geologic map of the Bruin quadrangle oft and Carter Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GC 2 coach 2, 24, 2000 along drainage lines. Throughout the quadrangle, groundwater is hard or very hard, and may contain salt or hydrogen sulfide, especially at depths greater than 100 ft. The Ordovician and Mississippian limestones Pointdexter, O.F., 1924, quoted in Jillson, W. R., Glaciation in eastern Kentucky: Pan-American Geologist, v. 42, p. 125–132. generally yield more than 500 gal/day to over half of the wells drilled in valley bottoms and many wells drilled on hills may yield more than 50 gal/min to a few wells penetrating large, active solution cavities. The Ordovician limestones yield little water where overlain by the Devonian Ohio Shale, and Mississippian limestones vo, L.J., Kepferle, R.C., and Potter, P.E., 1977, Three Lick Bed: Useful stratigraphic marker i Upper Devonian shale in eastern Kentucky and adjacent areas of Ohio, West Virginia, an Locations of the 30 x 60 minute quadrangles covering Kentucky. The location of the generally yield little water where overlain by Pennsylvanian rocks. Detailed information by county is available Tennessee: U.S. Department of Commerce, National Technical Information Service, ERDA-MERC/CR-77-2, 56 p. in Carey and Stickney (2004a-c, 2005a,b). Rice, C.L., 1984, Sandstone units of the Lee Formation and related strata in eastern Kentucky: U.S. Geological Survey Professional Paper 1151-G, 53 p. Rice, C.L., Belkin, H.E., Henry, T.W., Zartman, R.E., and Kunk, M.J., 1994, The Fire Clay tonstein of the Appalachian Basin—Its distribution, biostratigraphy, and mineralogy, *in* Rice, C.L., ed., Elements of Pennsylvanian stratigraphy, central Appalachian Basin: Geological Society of America Special Paper 294, p. 84–104. ROME TROUGH Rice, C.L., Currens, J.C., Henderson, J.A., Jr., and Nolde, J.E., 1987, The Betsie Shale Member A datum for exploration and stratigraphic analysis of the lower part of the Pennsylvanian in the central Appalachian Basin: U.S. Geological Survey Bulletin 1834, 17 p. Sable, E.G., and Dever, G.R., Jr., 1990, Mississippian rocks in Kentucky: U.S. Geological Survey Professional Paper 1503, 125 p. SANDY HOOK ANTICLINE Swanson, V.E., 1960, Oil yield and uranium content of black shales: U.S. Geological Survey Professional Paper 356-A. 44 p. meeting, June 3, 1960: Kentucky Geological Survey, ser. 10, Special Publication 3, p. 10–28. Thomas, W.A., 1991, The Appalachian-Ouachita rifted margin of southeastern North America: Geological Society of America Bulletin, v. 103, no. 3, p. 415–431. Weir, G.W., 1975, Geologic map of the Owingsville quadrangle, Bath and Montgomery Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1242, scale 1:24,000. Crab Orchard Group Upper Ordovician

Conasauga Group

Rome Formation

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