The Geological Society of America
Field Guide 12
2008

The Illinois-Kentucky Fluorite District, Hicks Dome, and Garden of the Gods in southeastern Illinois and northwestern Kentucky

F. Brett Denny*
Illinois State Geological Survey, 5776 Coal Drive, Suite 2, Carterville, Illinois 62918-3521, USA

Alan Goldstein*
Indiana Department of Natural Resources, 201 West Riverside Dr., Clarksville, Indiana 47129, USA

Joseph A. Devera*
Illinois State Geological Survey, 5776 Coal Drive, Suite 2, Carterville, Illinois 62918-3521, USA

David A. Williams*
Kentucky Geological Survey, Kentucky Geological Survey, 1401 Corporate Ct., Henderson, Kentucky, 42420, USA

Zakaria Lasemi*
Illinois State Geological Survey, 615 East Peabody Drive, Champaign, Illinois, 61820-6964, USA

W. John Nelson†
Illinois State Geological Survey, 615 East Peabody Drive, Champaign, Illinois, 61820-6964, USA

ABSTRACT

Minerals have been extracted from the Illinois-Kentucky Fluorite District for over 170 years. Theories concerning the inter-relationship between the fluorite mineralization, tectonism, and igneous activity will be discussed by several geologists during this field trip. The Columbia mine (vein deposit) will be visited in Kentucky, and the only mine currently producing fluorite in this district, the Hastie Limestone Quarry (strata-bound deposit), will be visited in Illinois. The mining history of this region will be explained at the American Fluorite Museum, where numerous mineral specimens can be examined. The Hicks Dome, a Permian crypto-volcanic feature (?) in Illinois, will also be discussed. The trip will conclude with a walking tour at the Garden of the Gods Recreational Area to view the Eagle Valley Syncline and Lower Pennsylvanian units.

Keywords: fluorite, Hicks Dome, Mississippi Valley–type deposit, Illinois-Kentucky Fluorite District, fluorspar, Permian igneous intrusion

*Field trip leaders.
†Honorary field trip leader; retired.

Denny, F.B., Goldstein, A., Devera, J.A., Williams, D.A., Lasemi, Z., and Nelson, W.J., 2008, The Illinois-Kentucky Fluorite District, Hicks Dome, and Garden of the Gods in southeastern Illinois and northwestern Kentucky, *in* Maria, A.H., and Counts, R.C., eds., From the Cincinnati Arch to the Illinois Basin: Geological Field Excursions along the Ohio River Valley: Geological Society of America Field Guide 12, p. 11–24, doi: 10.1130/2008.fld012(02). For permission to copy, contact editing@geosociety.org.

REGIONAL TECTONIC SETTING

W. John Nelson

The Illinois-Kentucky Fluorite District is located within one of the most intensely faulted areas of the North American Midcontinent (Fig. 1), with vertical offsets of hundreds of meters along several fault zones. Faulting includes normal extensional with horst and grabens several kilometers in length, high angle reverse, and strike-slip. Tectonic activity has been episodic, and major periods of movement have been documented in the Cambrian, Pennsylvanian, Permian, and Cretaceous Periods (Nelson, 1991). The complex array of faults began forming at least 500 million years ago, and in some areas earth movements are still in progress (Nelson, 1995). Faults are essential to mineralization as pathways for hydrothermal fluids, resulting in bedded-replacement as well as vein deposits.

The oldest units exposed within the field trip area crop out at the crest of Hicks Dome. The Hicks Dome is a crypto-volcanic structure that exposes Devonian rocks on top, and Mississippian rocks along its flanks (Nelson, 1995). Mississippian rocks are also exposed along the crest of the Tolu Arch (Baxter and Desborough, 1965). Pennsylvanian rocks are present to the north, in the Eagle Valley Syncline, and in down-thrown fault blocks along the Reelfoot Rift and Rough Creek Graben.

Tectonic structure in the Fluorite District is inherited from rifting that took place in the Cambrian during an episode of widespread continental break-up. A narrow fault-bounded trough developed, curving from northeast in southern Illinois to east-west in Kentucky. This trench was bounded on the northwest by the Lusk Creek Fault Zone, on the north by the Rough Creek Fault System, and on the south by the Tabb and Pennyrile Fault Systems. These normal faults dipped steeply near the surface and less steeply at depth. The trough became an arm of the sea where Lower (?) and Middle Cambrian sediments accumulated to thicknesses of more than 3 km in places (Bertagne and Leising, 1991; Potter et al., 1995). By the Late Cambrian, the area had stabilized, but its faults remained as permanent zones of weakness that were periodically reactivated by changes to the regional stress regimen. For example, portions of the Rough Creek and Pennyrile Fault Systems underwent renewed movement during the Acadian orogeny in Middle to Late Devonian time (Nelson and Marshak, 1996).

Effects of the late Paleozoic Alleghenian orogeny were far more profound. Compression along a northwest-southeast axis reactivated many Cambrian-age rift faults with reverse motion, particularly along the northern and northwestern margins of the rift (Nelson and Lumm, 1987). Vertically dipping strike-slip (?) faults of small displacement developed parallel with the stress axis. Ultramafic igneous activity, dated as Early Permian (ca. 270 Ma), accompanied these events (Zartman et al., 1967). The climactic event was creation of Hicks Dome. Centered in Hardin County, Illinois, Hicks Dome is a nearly circular uplift 12 km in diameter, with more than 1 km of structural relief. Seismic reflection data reveal that doming is seated within Precambrian crystalline basement (Potter et al., 1995). This unique structure is believed to be the product of explosive and intrusive igneous activity (Brown et al., 1954; Bradbury and Baxter, 1992; Potter et al., 1995).

After the Alleghenian orogeny, the stress field evolved from compression to northwest-southeast crustal extension. Fault blocks uplifted during the compressive phase now sank, leaving narrow slices of older rock wedged within the fault zones (Nelson and Lumm, 1985). With roughly one mile (1.6 km) of total extension, the great array of northeast-trending horsts and grabens of the Fluorspar Area Fault Complex developed (Hook, 1974; Trace, 1974; Trace and Amos, 1984). It is these extensional faults that served as pathways for hydrothermal fluids, resulting in the vein deposits of the district. Precise timing of tectonic and mineralization events remains poorly constrained. Globally, the crustal extension in the Fluorspar District is most likely related to the breakup of Pangea during Triassic and Jurassic time.

Earth movements continued in the western part of the district through Tertiary and Quaternary Periods. Resulting structures are mostly narrow grabens oriented northeast along with cross-faults oriented north-south to northwest. The overall fracture pattern suggests pull-apart grabens having a component of right-lateral wrenching (Nelson et al., 1999). The present-day stress field is compressive along an east-west to ENE-WSW axis. Deeply buried rift structures in the vicinity of New Madrid, Missouri, continue to move in this most active earthquake region of the Midcontinent.

FLUORITE MINERALIZATION

F. Brett Denny and Alan Goldstein

The Illinois-Kentucky Fluorite District encompasses an area of approximately 1,000 square miles (Baxter et al., 1989). The mineral deposits occur in veins along fault zones and as strata-bound bedding-replacement deposits. Typically, veins and strata-bound deposits are elongate parallel with northeasterly trending fault zones in the region (Fig. 2). Fluorite mineralization is most always associated with a carbonate unit in both the vein deposits and the strata-bound deposits. The largest deposits of fluorite were consistently found in the Ste. Genevieve Limestone. The Renault Limestone above and the St. Louis Limestone below also hosted moderate amounts of fluorite (Fig. 3). Fluorite gravel lag deposits were also mined at several locations.

Fluorite veins commonly are 3–12 feet (1–4 m) in width and are mineralized along strike of the fault for several hundred feet. Large veins may extend vertically for over 300 ft (100 m) and have widths of up to 45 ft (15 m). Fluorite in the veins occurs in fissures as filling, as replacement of vein calcite, and as replacement of the limestone wall rock. The fluorite in the bedding-replacement deposits is commonly banded, with alternating light and dark bands of fluorite. The local miners called this banded texture coon-tail ore. The strata-bound deposits are capped by impermeable roof material of either a shale or tight sandstone (Fig. 4). These deposits are generally horizontal but may dip

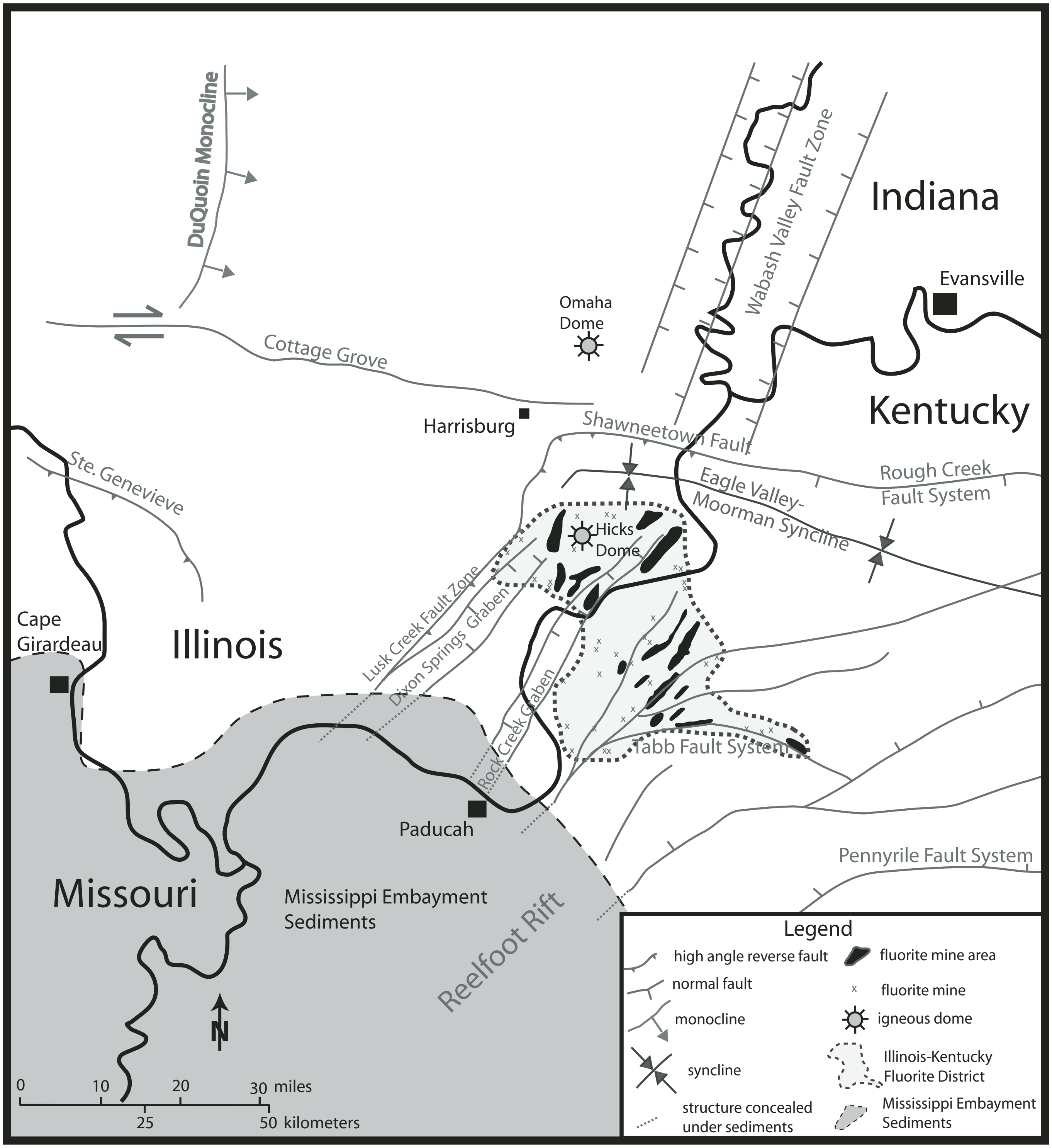

Figure 1. Major tectonic structures in the Illinois-Kentucky Fluorite District (adapted from Nelson, 1995). A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.

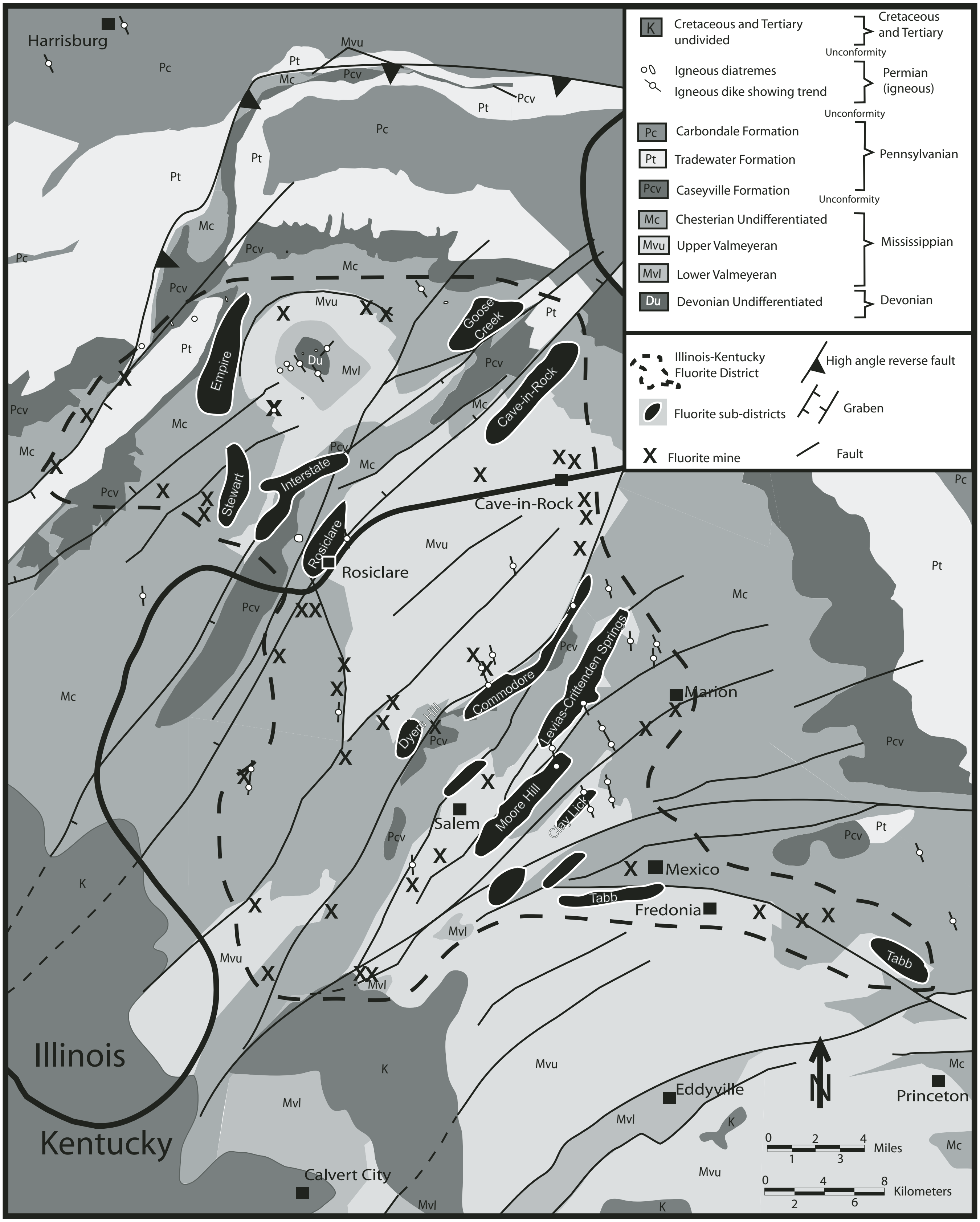

Figure 2. Generalized geologic map of the Illinois-Kentucky Fluorite District. (compilation based on several Illinois State Geological Survey and Kentucky Geological Survey geologic maps.) A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.

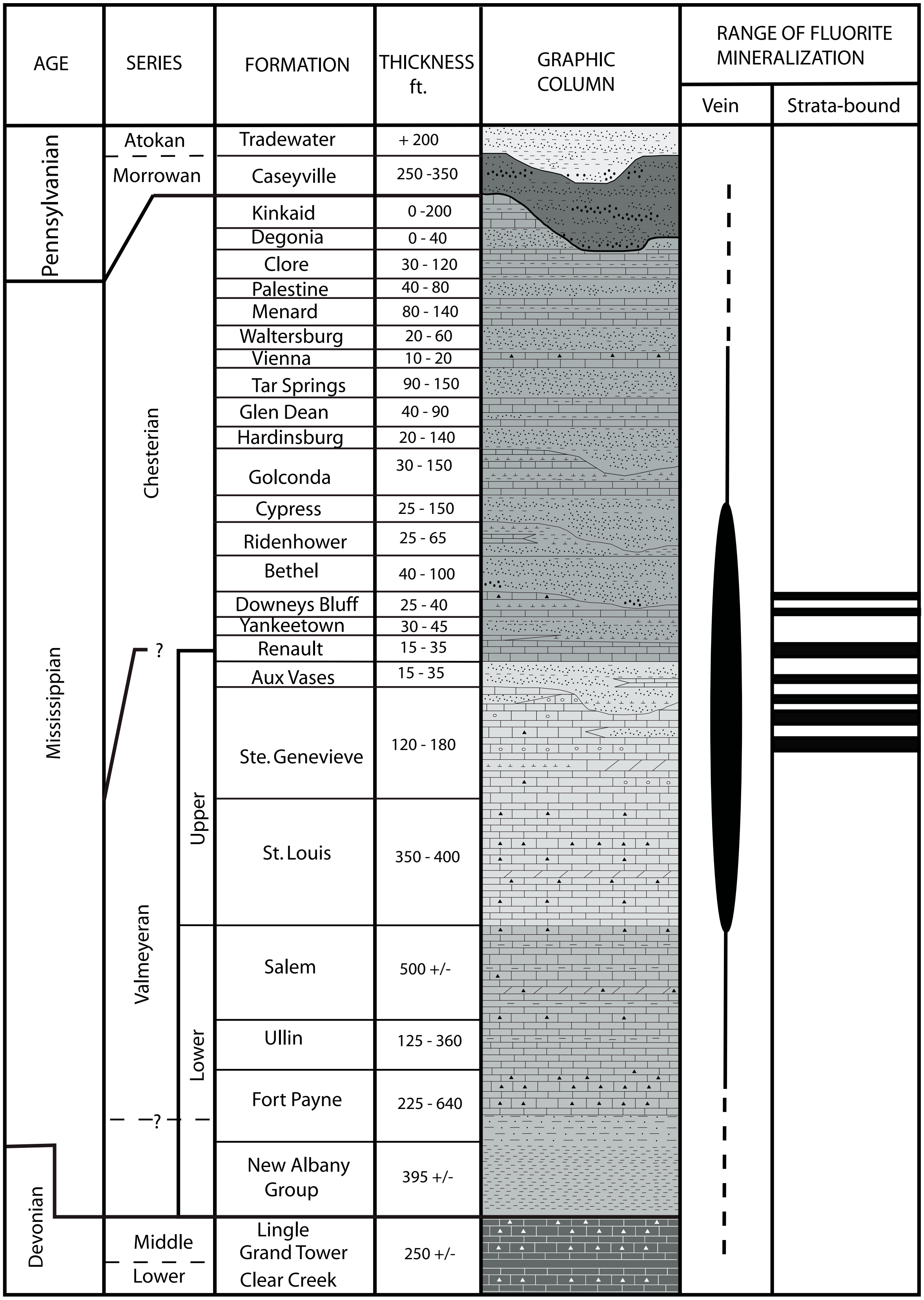

Figure 3. Stratigraphic column with range of vein and bedding replacement deposits for the Illinois-Kentucky Fluorite District. Modified after Grogan and Bradbury (1968). Formation thicknesses from Trace (1954); Thurston et al. (1954); Hardin (1955); Williams and Duncan (1955); Baxter et al. (1963); and Baxter and Desborough, (1965). A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.

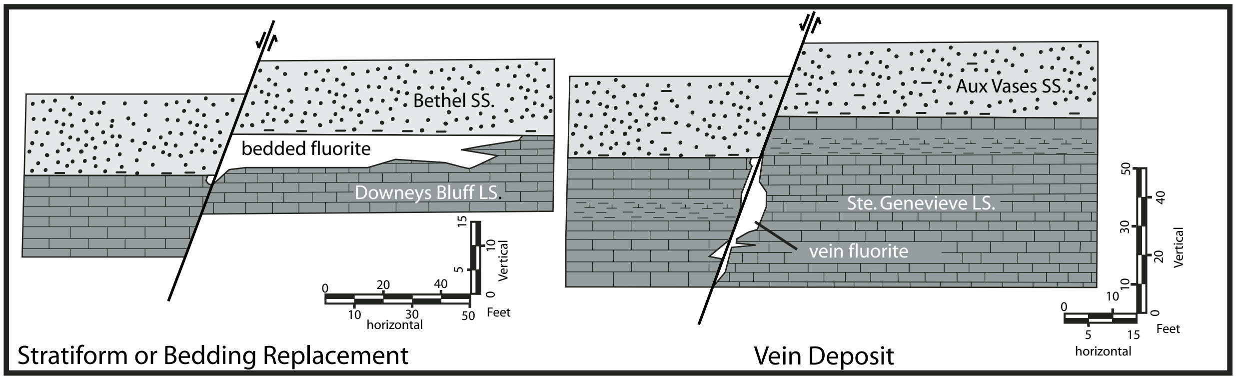

Figure 4. Idealized bedding replacement and vein type fluorite deposit within the Illinois-Kentucky Fluorite District. A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.

slightly. Some bedding-replacement deposits are located near small faults, joints, or fractures. The largest deposits were more than 4 miles (6.4 km) in length, but most were much shorter, with widths approaching 200 ft (70 m).

Fluorite occurs in a wide range of colors in this district with colorless, purple and yellow being the most common. Blue is widespread, but less common. One mine on Hicks dome produced some green fluorite, and a nearby mine yielded pinkish crystals, but those should be considered anomalous. In addition to fluorite, a large quantity of zinc (sphalerite and smithsonite) has been mined within the Illinois-Kentucky Fluorite District. The largest zinc deposits in Kentucky are associated with igneous dikes. Some have been found to be in direct contact with dikes such as those in the Hutson and Old Jim mines (McGrain, P., *in* McDowell, 2001). Other minerals that have been reported in the district include galena (PbS), calcite ($CaCO_3$), dolomite ($Ca,Mg(CO_3)_2$), barite ($BaSO_4$), pyrite (FeS_2), chalcopyrite ($CuFeS_2$), quartz (SiO_2), celestite ($SrSO_4$), cerussite ($PbCO_3$), greenockite (CdS), malachite ($Cu_2CO_3(OH)_2$), smithsonite ($ZnCO_3$), witherite ($BaCO_3$), strontianite ($SrCO_3$), benstonite ($(Ba,Sr)_6 (Ca,Mn)_6 Mg(CO_3)_{13}$), and alstonite ($Ba,Ca(CO_3)_2$) (Goldstein, 1997).

Researchers have utilized stable isotopes and fluid-inclusion chemistry (analysis of halogen and noble gases trapped within the fluid inclusions) to determine the origin of the fluorite deposits within the Illinois-Kentucky Fluorite District. For fluid inclusions in the Cave-in-Rock District, homogenization temperatures between 125 and 150 °C (Spry et al., 1990), and salinities in the range of 19–21 wt% NaCl were reported (Richardson and Pinckney, 1984). Oxygen isotope data indicate that the ore fluids originally circulated in sedimentary formations, while sulfur in the fluids was derived from both petroleum and basement sources (Richardson et al., 1988). Helium isotope data indicate that at least a portion of the helium present within the Illinois-Kentucky Fluorite District is from an upper mantle source and probably related to the alkaline igneous bodies (Kendrick et al., 2002). The fluids responsible for fluorite mineralization in the Illinois-Kentucky Fluorite District were quite acidic ($pH < 4$) and were charged with fluorine most likely expelled from alkaline igneous sources (Plumlee et al., 1995).

Several attempts have been made to date the age of the fluorite within the Illinois-Kentucky Fluorite District. Symons (1994) reported a late Jurassic date of fluorite mineralization based on paleomagnetic analysis. Chesley et al. (1994) reported an early Permian date based on a $^{147}Sm/^{144}Nd$ isochron for fluorite. Ruiz et al. (1988), using strontium isotope data, reported an early Jurassic date. Harder (1987, *in* Symons, 1994) reported an age based on fission-track analysis that straddles the Jurassic-Cretaceous boundary. Brannon et al. (1997) reported a lower Jurassic age based on ore stage calcite U-Pb and Th-Pb isotopes.

IGNEOUS ACTIVITY AND HICKS DOME

F. Brett Denny

Ultramafic intrusive rocks are present in southern Illinois and western Kentucky and can be found within the Illinois-Kentucky Fluorite District (Fig. 5). Alkaline igneous rocks that are dark green, porphyritic to inequigranular with a fine-grained groundmass were first recognized along the Tolu Arch and Hicks Dome in the early 1900s. Johannsen (*in* Bain, 1905) first described these rocks as mica peridotites. The igneous bodies occur as sills, dikes, and pipes and have been described and studied by English and Grogan (1948), Clegg and Bradbury (1956), Koenig (1956), Bradbury and Baxter (1992), and Denny et al. (2002). Primary minerals are phlogopite, pyroxenes, olivine (altered to serpentine), apatite, calcite, garnet, perovskite, titanite, chromite, and spinels. The rocks have been extensively altered, and serpentine and chlorite are abundant. Where these rocks are highly altered, with little primary mineralogy remaining, they commonly have been termed lamprophyre (Baxter et al. 1989). The composition and texture of these rocks indicate they originated within the upper mantle, ascending at supersonic velocities along cracks in the Precambrian basement (Denny, 2005). Recent analysis of the ultramafic rocks from the region indicates they may be classified as alnöite (Lewis and Mitchell, 1987; Sparlin and Lewis, 1994; Denny, 2005). Alnöite is an ultrabasic-lamprophyre containing

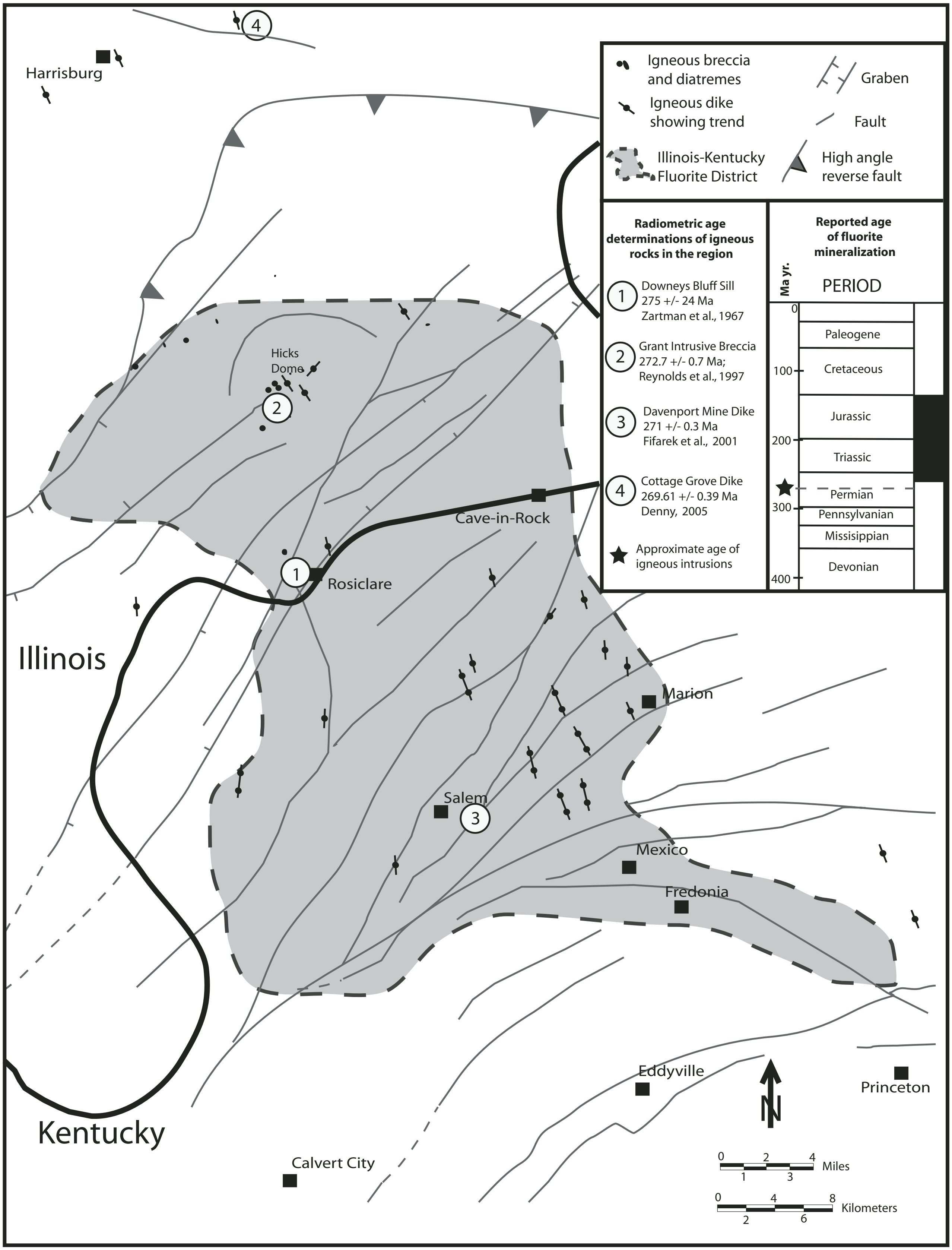

Figure 5. Radiometric ages for igneous rocks in southeastern Illinois and northwestern Kentucky, and reported age determinations of fluorite mineralization. A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.

biotite with or without olivine, melilite, carbonate, and commonly perovskite. This silica-deficient igneous rock may grade into kimberlite with an increase in forsterite and diminution of augite, or into carbonatite with an increase of carbonate (Williams et al., 1982).

The age of the igneous bodies throughout the Illinois-Kentucky Fluorite District has been determined by radiometric dating techniques to be ca. 270 Ma (Fig. 5) or early Permian (Zartman et al., 1967; Reynolds et al., 1997; Fifarek et al., 2001; and Denny, 2005). Breccia (diatremes ?) at Hicks Dome (Fig. 6) were studied by Bradbury and Baxter (1992), who proposed three classifications for these breccias based upon their clast geometry and composition: (1) vent breccias, (2) carbonatitic breccias, and (3) shatter breccias. The shatter breccias are dike-like intrusive bodies containing angular to sub-rounded clasts of country rock that were ripped up and incorporated during ascent. Carbonatitic breccias are composed of both igneous and sedimentary clasts set in a matrix of igneous carbonate. Bradbury and Baxter (1992) theorized this style of breccia was a result of explosive release of CO_2-rich gas exsolving from an alkaline ultramafic magma at depth. Vent breccias are described as bodies of indeterminate form, usually silicified, and may contain sedimentary fragments originating from great depths. Some of these breccia pipes may be considered to be diatremes (breccia filled volcanic vents).

The composition and texture of the ultramafic rocks indicate they are similar to rocks that carry diamonds. Gurney (1984) developed methods to evaluate the potential for diamonds within an ultramafic rock utilizing the composition of garnets. One method utilizes a binary plot of Cr_2O_3 versus CaO on garnets. Garnets analyzed in an ultramafic dike in Saline County, Illinois, are high CaO and low Cr_2O_3 types, suggesting that this dike probably does not host diamonds. Certainly many more samples would need to be analyzed to estimate the diamond potential for the entire igneous complex. The economic potential of an ultramafic dike in Kentucky is being explored by Marum Resources Inc. Marum drilled several boreholes into a "kimberlite" dike in Kentucky (Lollypop Kimberlite), the deepest of which reached 2214 ft (686 m) to test for diamonds. No diamonds were initially detected, but the final results have not been made available[1].

Summary

The relationship of the igneous activity and the fluorite mineralization of the Illinois-Kentucky Fluorite District have been debated for many years (e.g., Weller, 1927; Bastin, 1931; Plumlee et al., 1995; and Kendrick et al., 2002). The trend of the mineral deposits is obviously parallel with the northeasterly trending fault zones (Fig. 2). The trend of the ultramafic dikes and the Tolu Arch is west of north, oblique to the northeasterly trend of the mineralized faults and the individual mineral sub-districts. It is likely the northwesterly trend of these igneous intrusions is controlled by the dominant fracture pattern within the Precambrian basement rocks through which the igneous bodies ascended (Denny, 2005). The dominant fracture pattern of the Precambrian rocks in the Midcontinent is northwesterly (Marshak and Paulsen, 1997), similar to the strike of the majority of the igneous dikes in the region (Denny 2005).

Mineralization within the Illinois-Kentucky Fluorite District probably results from an acidic brine fluid, charged with fluorine and carbon dioxide derived from alkaline magmas (Plumlee et al., 1995). This brine may have been concentrated within the down-dropped portion of the Reelfoot Rift. As these complex fluids migrated through the region, they were further concentrated along the crest of the uplifted Tolu Arch (much like a structural oil trap). The fluids were then funneled along the northeasterly trending fractures and fault zones possibly during periods of major regional tectonic adjustment (see "Regional Tectonic Setting"). Contact between the acidic fluids and calcium-rich carbonate formations resulted in precipitation and ore formation. A range of ages of emplacement of the fluorite, reported by various authors from Permian through Jurassic, implies this process may have been episodic over millions of years after the Permian igneous activity. The low temperature of crystallization of these deposits is consistent with this assumption. It is furthermore suggested that the deposits of the Illinois Kentucky District are significantly different from other Mississippi Valley–type deposits to warrant classification as a fluoritic subtype of the Mississippi Valley–type deposit.

THE HISTORY OF THE ILLINOIS-KENTUCKY FLUORITE DISTRICT

Alan Goldstein and David A. Williams

The first attempt at mining ore in the Illinois-Kentucky Fluorite District was at the Columbia Mine near Marion, Kentucky, in 1835. A consortium of businessmen that included President Andrew Jackson attempted to extract silver from galena. Unfortunately, the concentration of silver in the galena in this district is very low and they were not successful. A short time later the Royal mine (also called the Royal Silver mine) opened near Smithland, Kentucky. Mines in the fluorspar district produced galena as the primary ore for much of the nineteenth century, and the fluorite was a waste product. In 1839, a well sunk in southern Illinois encountered lead ore (galena). The first operating mine in Illinois started in 1842 near Rosiclare and produced ore for eight years (Bastin, 1931). A process that utilized fluorite as a flux in the production of steel was discovered in the 1880s, resulting in a rejuvenation of mining within the Illinois-Kentucky Fluorite District.

The most important area of mining at the beginning of the twentieth century was near the Ohio River near the town of Rosiclare, Illinois. Thick veins of fluorite were mined extensively, and the proximity to the Ohio River made transportation to the steel mills relatively inexpensive. Some of the underground mines at

[1]Marum Resources INC., Suite 102, 5004 Elbow Drive SW, Calgary, Alberta Canada, T2S 2L5; 2003 Press Release (http://www.marumresources.com/id42.htm).

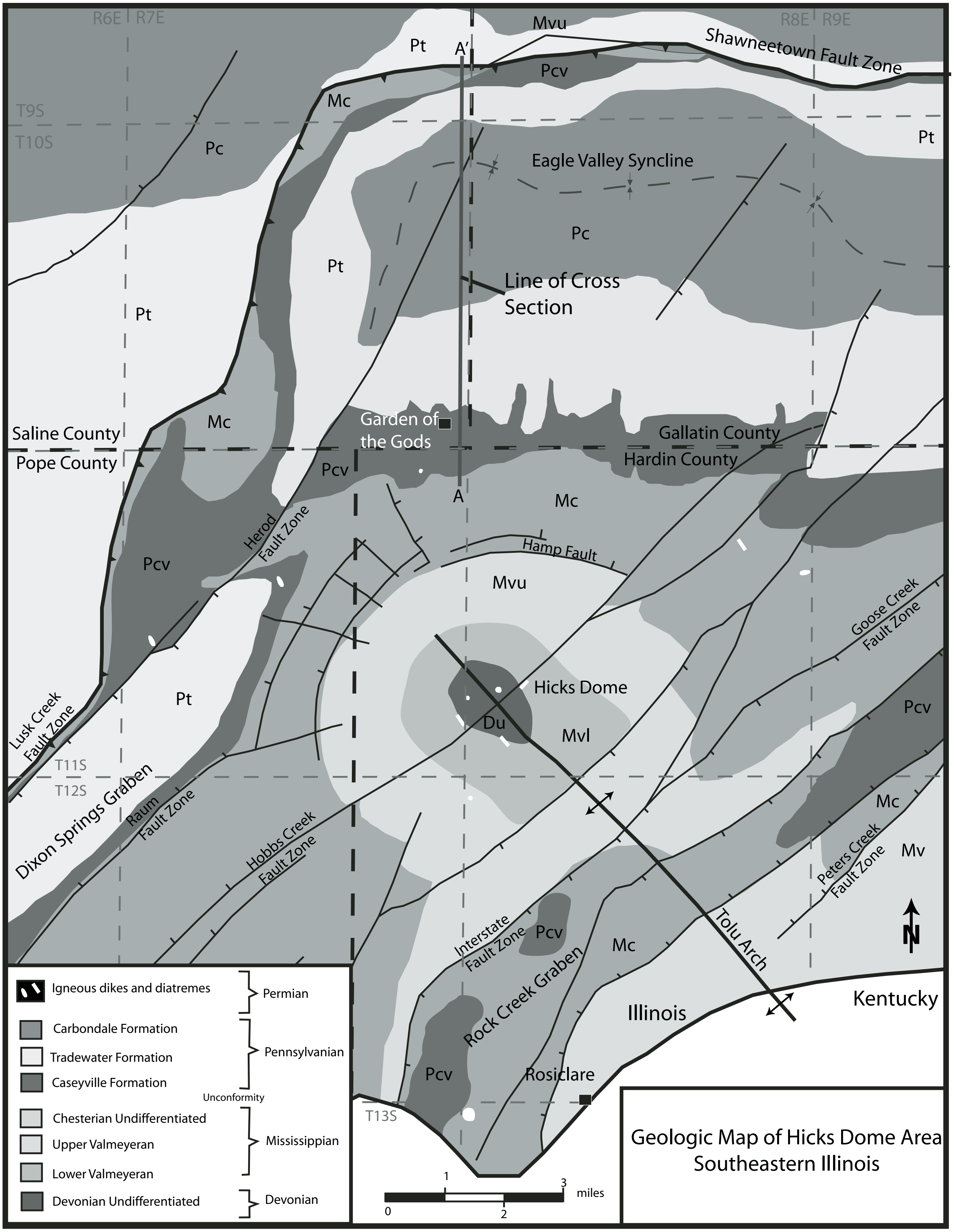

Figure 6. Geologic map of the Hicks Dome and Eagle Valley Syncline. Modified from Baxter et al. (1963); and Baxter and Desborough, (1965). A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.

Rosiclare encountered significant amounts of water. One mine which was tunneling underneath the Ohio River accidentally punched into an aquifer below the riverbed. The resulting “leak” eventually flooded every mine along the vein. Equipment was salvaged as large pumps slowed the influx of water, but ultimately the battle was lost. As a result, mine activity shifted to shallow deposits near Cave-in-Rock for most of the 1920s and 1930s. The famous Crystal mine and the less well known but productive Victory mine were opened in the 1930s. World War I caused an increase in exploration for fluorite because of unprecedented demand in the manufacturing of steel. Many small mines were opened, but no large deposits were discovered during this time. During World War II, the flooded mines in Rosiclare were dewatered and underground mining was resumed.

The 1940s brought further exploration, particularly north of Cave-in-Rock. The most significant discovery was made by the Minerva Oil Company at the northeastern edge of the Cave-in-Rock sub-district. Named the Minerva No. 1 mine, its orebody turned out to be among the largest bedding-replacement deposits in the world—some 20,000 ft long. Mining continued through the 1950s until the mid 1970s when production started slowing down. Imports of fluorite from South Africa and Mexico created pricing pressures on the U.S. market. When fluorite prices became depressed, zinc ores were mined. A number of mines in Kentucky were exclusive zinc producers (sphalerite and smithsonite). The Ozark-Mahoning mill in Rosiclare had modifications made specifically to concentrate zinc, although the last upgrade of the mill was completed a few years before mining operations ceased. Mining within the Illinois-Kentucky Fluorite District became unprofitable in the mid 1990s as cheap Chinese fluorite flooded the world market. In 1996, the last mine within the Illinois-Kentucky Fluorite District, the Minerva, closed.

Various companies built mills around the district during the twentieth century. Most were razed intentionally or by arson. Two of the most recently constructed mills remain: the Ozark-Mahoning mill in Rosiclare, Illinois, and the Babb-Barnes mill near Salem, Kentucky. Both are currently owned by Hastie Mining and Trucking. The foundations of other mills remain, including the Hutson and Lafayette in Kentucky and the Crystal, Heavy Media, Victory, and Rosiclare Lead and Spar in Illinois. Abandoned mine sites are mostly rock piles with scattered concrete structures. Only a couple mine headframes remain. In Illinois, the Annabel Lee mine is still visible from Illinois Highway 1. A short headframe, a relict from the old Rosiclare Lead and Spar Company site (now the location of the American Fluorite Museum), also remains. In Kentucky, the headframe of the Babb mine sits amidst a fluorspar flotation mill, while a few miles away, the Hutson mine’s steel and wood headframe and an ore tipple remain.

During much of its 170 year existence, the mines of the Illinois-Kentucky Fluorite District produced the largest amount of fluorite in the western hemisphere. More than 7 million tons of fluorite was produced. Recently, China reduced the amount of fluorite for export and interest in tapping new or partially mined deposits within the Illinois-Kentucky Fluorite District has been renewed (see Appendix 1). The only production currently within the Illinois-Kentucky Fluorite District is at the Hastie limestone quarry, where the open pit mines pass through abandoned underground fluorite workings. Modern applications for fluorite include the production of hydrofluoric acid, metal refining and smelting, various chemical processes, the ceramic and glass industries, and optics.

AMERICAN FLUORITE MUSEUM AND THE HASTIE QUARRY

Zakaria Lasemi

The Hastie Quarry extracts Mississippian carbonate rock for aggregate and construction use. The quarry is located northwest of Cave-in-Rock and is mining through an area that contains abandoned fluorite workings. This quarry is the only mine that is extracting fluorite in the United States. Production from these workings is highly variable, but this quarry offers excellent exposures of the former underground adits in the quarry high wall. The banded nature of the bedding-replacement deposits can be observed here along with volume reduction or shrinkage of the overlying roof strata. This quarry lies at the southern end of the Cave-in-Rock sub-district and quarries mainly the Ste. Genevieve Limestone.

The American Fluorite Museum is located at the former Rosiclare Lead and Fluorspar property in Rosiclare, Illinois. The museum contains an excellent collection of minerals from this mining district along with mine memorabilia.

GARDEN OF THE GODS

Joseph A. Devera

The Garden of the Gods is located on the southern limb of the Eagle Valley Syncline within the confines of the Shawnee National Forest, southeasternmost Saline County, Illinois (Fig. 6). Lower Pennsylvanian sandstones stand out as rounded high knobs and pinnacles resulting from millions of years of water and wind erosion. Now, only remnants of a fluvial dominated, deltaic system that existed 320 million years ago create a high vista and panoramic view to the north of caricatures like Camel Rock and Monkey Face. Farther north, one can see the northern limb of the Eagle Valley Syncline as a distant ridge (Fig. 7).

The Garden of the Gods is composed of the Pounds Member of the Lower Pennsylvanian (Morrowan) Caseyville Formation. It is a mature quartz arenite, poorly sorted, with fine to coarse quartz sand grains and numerous milky white, rounded quartz pebbles. Some of the beds contain quartz pebble conglomerates. In the area, both the lower Battery Rock Member and Pounds Member coalesce to form one massive cross-bedded series of sandstone beds of the Caseyville Formation. The Caseyville is not only thought to have been fluvial deltaic but also estuarine in places as goniatites have been reported in shales that occur between the Battery Rock and Pounds Members nine miles east of this area (Devera et al., 1987).

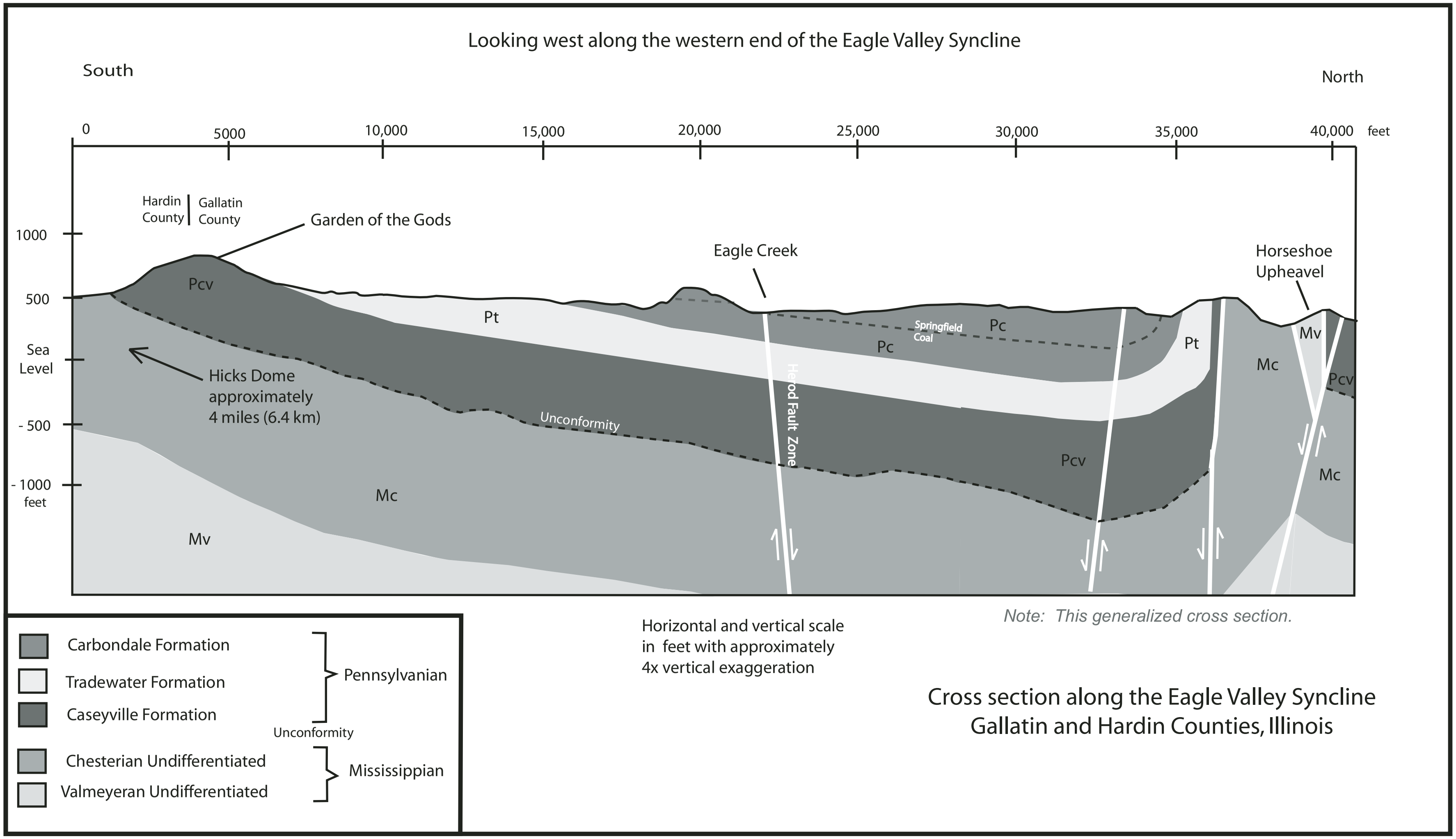

Figure 7. Cross section along the Eagle Valley Syncline. A color version of this figure is available as item 2008108 in the GSA Data Repository at www.geosociety.org/pubs/ft2008.htm or on request from editing@geosociety.org.