Geology and Fluorspar Deposits of the Levias-Keystone and Dike-Eaton Areas Crittenden County, Kentucky

GEOLOGICAL SURVEY BULLETIN 1122-E

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By ROBERT D. TRACE

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A description of typical examples of the fault systems and their associated minerals

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GEOLOGY AND FLUORSPAR DEPOSITS OF THE LEVIAS-KEYSTONE AND DIKE-EATON AREAS, CRITTENDEN COUNTY, KENTUCKY

By Robert D. Trace

ABSTRACT

The fault systems of the Levias-Keystone and Dike-Eaton areas, in the Kentucky-Illinois fluorspar district, are a complex northeastward-trending system and a simple northwestward-trending system of steeply dipping normal faults, associated in part with a lamprophyre dike. Fluorspar mining started in the area about 1900 and, as of 1945, more than 200,000 tons of crude ore probably has been mined; most of the ore was from the Levias-Keystone area. A small quantity of zinc and lead ore also is present in the Dike-Eaton area.

The deposits are localized along faults that displace flat-lying or low-dipping limestones, sandstones, and shales of the Meramec and Chester series of Mississippian age. Movement along most of the faults was principally vertical, with displacement as much as 600 feet. Some horizontal movement occurred along at least one fault. Geologic mapping of the surface and data from underground workings have revealed 13 faults in an area of four-fifths of a square mile. Only a few of these faults are known to contain economically important deposits of fluorspar.

The most abundant vein minerals are calcite and fluorite with subordinate quantities of sphalerite, galena, barite, and quartz. Some weathering products of sphalerite and galena are present also. The veins are dominantly calcite that contains fluorite lenses but in places are mainly fluorite having lesser quantities of calcite. Sphalerite- and galena-bearing deposits are present in the Dike-Eaton area. The ore bodies mainly are the result of fissure filling and replacement of calcite by fluorite; in addition a small amount of limestone wallrock probably has been replaced. Residual concentrations of high-grade fluorspar in the overburden above faults have yielded some so-called gravel fluorspar. The position of the veins within the faults may be related to one or more factors such as type of wallrock, change in dip of the fault, and amount of displacement.

INTRODUCTION

LOCATION AND GENERAL FEATURES

The Levias-Keystone and Dike-Eaton areas are in the Kentucky-Illinois fluorspar district, which is traversed by the Ohio River in southern Illinois and western Kentucky. The areas are about 5 miles west of Marion, Crittenden County, Ky., and can be reached by U.S. Highway 60, which crosses the northern part of the Dike-Eaton area, and by Kentucky State Highway 297 (fig. 1).

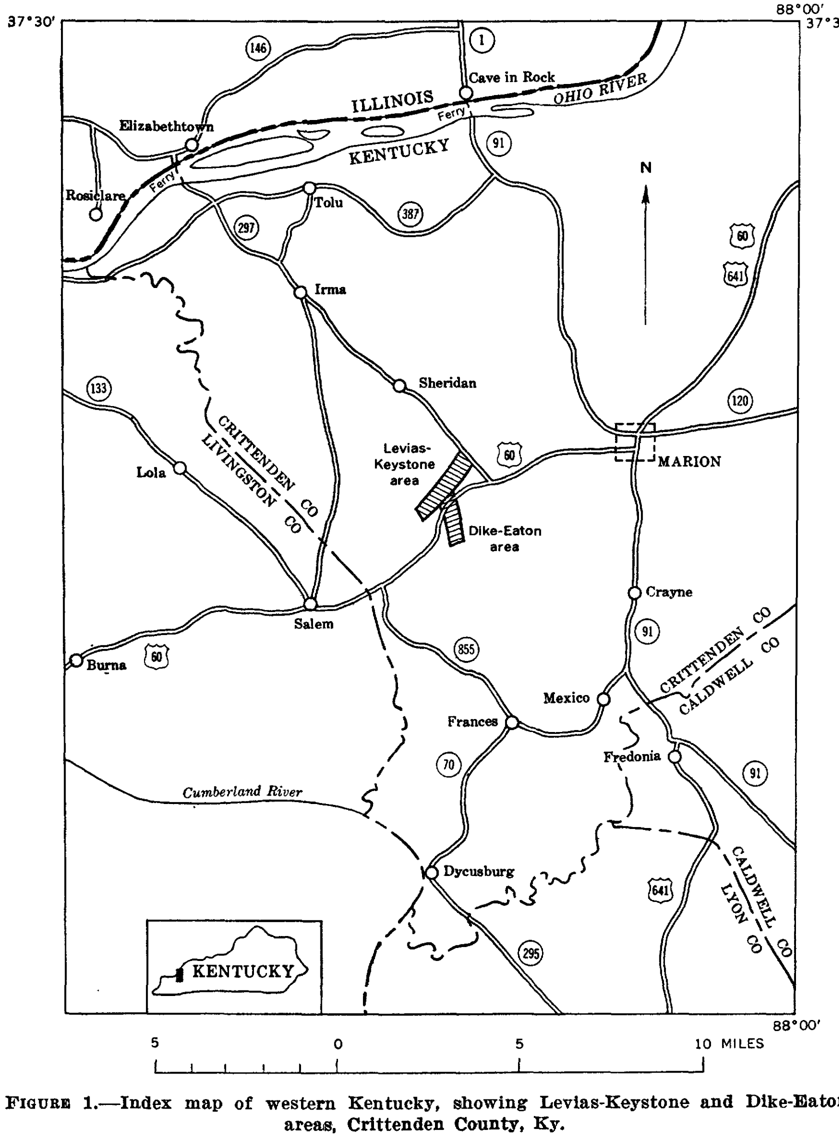

FIGURE 1.—Index map of western Kentucky, showing Levias-Keystone and Dike-Eaton areas, Crittenden County, Ky.

The Levias-Keystone area is in the south-central part of the fluorspar district and contains one of the several major northeastward-trending normal-fault systems that have sliced the district into a complex fault-block pattern; the largest fault blocks are 5 to 20 miles long and 1 to 2 miles wide. The Dike-Eaton area to the southeast contains two northwestward-trending faults and one of the many northwestward-trending mafic dikes that are reported to occur from Saline and Gallatin Counties, Ill., to near Princeton, Ky. (Oesterling, 1952). For a general description of the Kentucky-Illinois fluorspar district, see Weller and others (1952), Weller and Sutton (1951), and Williams and Duncan (1955).

The Levias-Keystone area is along the southeastern slope of a northeastward-trending ridge, and the Dike-Eaton area extends southeastward across a broad valley toward the northeastward-trending ridge along the Moore Hill fault system. Most of the Levias-Keystone area is wooded, whereas most of the Dike-Eaton area is cultivated. Elevations in the areas range from 440 to 620 feet above mean sea level; thus, the maximum relief is 180 feet. The areas are drained by Coefield, New Salem, and Dry Creeks and their tributaries. In general, the hills are capped by sandstones of the Chester series, and the broad valley is underlain by the Ste. Genevieve limestone of the Meramec series.

Mining activity apparently started in the areas about 1900, probably on the Eaton vein. Production from the two areas may have exceeded 200,000 tons of crude ore, although exact figures are not available. About 25,000 tons of crude ore are estimated to have been produced from the Dike-Eaton area, principally during World War II (Starnes, 1950, p. 3).

The principal mine is in the Levias-Keystone area and is called the Keystone mine. The mine has levels as deep as 500 feet, chiefly on a northeastward-trending fault zone which is called the Levias fault by Weller (1927, p. 109).

FIELDWORK

EARLIER WORK

Ulrich and Smith (1905, p. 104, pl. VIII) show the Columbia (Levias) fault and the "Eaton fissure" and mention a dike about 1 mile southeast of Levias. Also the Keystone mine is described briefly, and a few small mines in the southern part of the Dike-Eaton area are mentioned.

Currier (1923, p. 99–100) describes the Keystone mine and the prospects along the Dike and Eaton faults.

Weller (1927) and Weller and Sutton (1951) show the Levias, Dike, and Eaton faults. Weller (1927, p. 109) mentions the dike near Levias and describes the Levias fault. The geology of the Dike-Eaton area shown in this report is almost the same as that given in Weller and Sutton (1951). In the Levias-Keystone area, however, subsequent exploration has shown that the single fault described by Weller (1927) is actually a zone comprising several faults.

RECENT WORK

In 1942, when it became apparent that the known fluorspar reserves in the United States would not be adequate to meet accelerated demands made during World War II, the U.S. Geological Survey undertook the study of the country's fluorspar resources at the request of the War Production Board. The Kentucky-Illinois district was visited in June 1942 by L. W. Currier and James Steele Williams of the Geological Survey to plan a specific program for fieldwork. For the next 3 years Geological Survey geologists made detailed studies of the highly mineralized areas in the fluorspar district. Most of the results of these studies have been published (Williams and others, 1954–55), including the investigation of the area adjoining the Dike-Eaton area on the south (Thurston and Hardin, 1954). The minor discrepancies between plate 12 in the report by Thurston and Hardin and plate 1 in this report are due to differences in interpretation of the position of the Rosiclare sandstone member of the Ste. Genevieve limestone, which the writer places 5 feet higher than Thurston and Hardin placed it.

As a part of the program of detailed study, the Levias-Keystone and Dike-Eaton areas were mapped on a scale of 1 inch to 100 feet and underground maps were made of some of the mine workings. The surface geologic map was made mainly by Trace; the underground work was by G. C. Hardin, Jr., of the Geological Survey. The report is based almost entirely upon data gathered in 1942–45, except that a few critical outcrops were examined by Trace in 1956. The work was done under the general supervision of James Steele Williams and Ralph E. Van Alstine.

In 1944, the U.S. Bureau of Mines put down 9 diamond-drill holes along the mapped Dike and Eaton faults (Starnes, 1950) and 3 holes in the central part of the Levias-Keystone area (Starnes, 1947).

Several holes were drilled in 1942–43 by Hillside Fluor Spar Mines near the intersection of the Levias and Dike faults. Some of the drill cores were logged by the Geological Survey.

ACKNOWLEDGMENTS

Thanks are due to the operators in this area for their assistance and cooperation, particularly to Paul Richards of Hillside Fluor Spar Mines and independent operators J. S. Frazer, Mark Conyer, Ray Jennings, and the Gilless brothers.

GEOLOGY

The rocks exposed or cut by drilling in the areas are limestones, sandstones, and shales of the Meramec and Chester series of Late Mississippian age. The formations are either horizontal or dip less than 15°, except near faults, where the beds dip steeply and may be nearly vertical. A lamprophyre dike along the Dike Fault trends about N. 20° W. through the Dike-Eaton area (pl. 1).

The sedimentary rocks are broken by at least 13 normal faults. In general, the fault pattern of the Levias-Keystone area consists of two subparallel northeastward-trending faults and an intervening block 300 to 1,000 feet wide that is complexly faulted. The Dike-Eaton area contains two subparallel faults that trend about N. 20° W. and extend northward to the Levias fault system and southward to the northeastward-trending Moore Hill fault system (Thurston and Hardin, 1954, pl. 12).

The structural complexity of the northern half of the Levias-Keystone area in contrast to the apparent simplicity of the southern half may be misleading to the reader. This complexity reflects the greater amount of information obtained from the many underground workings and drill holes in the northern half; in the southern half, however, there are no records of any drill holes or accessible underground openings, and therefore the geologic interpretation is based entirely on outcrops and rocks found on mine dumps. Outcrops alone commonly yield insufficient data for one to map all the faults in an area, particularly within the narrow zones between the marginal faults.

SEDIMENTARY ROCKS

The formations exposed at the surface or cut in drill holes in the area include from oldest to youngest, the sequence of beds from the St. Louis limestone of the Meramec series to the Tar Springs sandstone of the Chester series all late Mississippian age (pl. 4). The scarcity of good exposures has greatly hindered positive identification of the formations, but this difficulty has been offset somewhat by the availability of considerable information from underground workings and from several diamond-drill holes. The stratigraphy of the St. Louis limestone and the Ste. Genevieve limestone of the Meramec series is obtained largely from several drill holes in the Dike-Eaton area. The stratigraphy of the Renault, Bethel, Paint Creek, Cypress, and Golconda formations of the Chester series is interpreted largely from drill holes in the northern half of the Levias-Keystone area, the stratigraphy of the Hardinsburg, Glen Dean, and Tar Springs formations is interpreted largely from drill holes located as much as 1½ miles northeast of the Levias-Keystone area. Because of complex faulting and, in places, poor core recovery, the Chester series had to be reconstructed from data from several drill holes and therefore may not be so accurately portrayed as the Meramec series.

The St. Louis limestone is not exposed at the surface, but the uppermost 100 feet was cut in USBM DDH (U.S. Bureau of Mines diamond-drill holes) 60 and 66 (pl. 1). The formation is medium-gray fine- to medium-grained limestone but contains common blue-gray chert nodules, especially in the lower 75 feet drilled. The upper 25 feet contains a few chert nodules and a few beds of medium-gray oolitic limestone. The contact of the St. Louis and the overlying Ste. Genevieve limestone (Fredonia limestone member) is drawn arbitrarily where the medium-gray limestone changes rather abruptly upward to a light-gray to white limestone; the contact also corresponds to the highest appearance of chert nodules (except for very rare chert nodules well up into the Ste. Genevieve limestone). As the upper 25 feet of the St. Louis contains only a few chert nodules and is oolitic in places, it could be considered a gradational zone between the two formations.

The Ste. Genevieve limestone was cut in all nine holes drilled by the U.S. Bureau of Mines in the Dike-Eaton area. This formation immediately underlies most of the Dike-Eaton area and forms the footwall of the Levias faults in the Levias-Keystone area. The Ste. Genevieve limestone is composed of the Fredonia limestone member at the base, the Rosiclare sandstone member, and the Levias limestone member at the top.

Within the areas described, the Fredonia limestone member can be divided into three units on the basis of lithology. A brief scanning of drill logs from other parts of the fluorspar district in Kentucky suggests that this threefold division might persist outside the mapped areas.

The lower unit of the Fredonia limestone member is about 135 feet thick and is mostly light gray, but contains some medium-gray coarse-grained oolitic limestone. Some beds of fine-grained to sublithographic limestone are present. Chert nodules and thin shale or shaly limestone beds are rare.

The middle unit of the Fredonia limestone member is about 20 feet thick and is light- and medium-gray fine-grained limestone with shaly partings common; a few beds of light-gray oolitic limestone and gray-green shale are present. This zone of limestone with shaly partings, shales, and scarcity of oolites is persistent throughout the mapped area.

The upper unit of the Fredonia limestone member is about 25 feet thick and the lithology is virtually the same as that of the lower unit.

The Rosiclare sandstone member is about 15 feet thick and is composed of sandy limestone that contains some sandstone, thin shale beds, and shaly partings. The unweathered sandy limestone is commonly greenish gray and fine grained. In outcrop, the sandy limestone is commonly leached to a fine-grained sandstone. For example, in an outcrop of the Rosiclare along the north side of the gravel road between Levias and Midway, the upper 10 feet is fine-grained sandstone in beds 3 to 6 inches thick; the underlying 5 feet is shaly sandstone, in beds about a quarter of an inch thick, and shale.

The Levias limestone member is about 25 feet thick and is indistinguishable from the upper and lower units of the Fredonia limestone member. Plate 1 includes part of the area where the Levias member was named and described by Sutton and Weller (1932, p. 439), who stated, "The new name Levias, with the type locality just east of the town of that name in Crittenden County, Kentucky, is now proposed for the uppermost member of the Ste. Genevieve between the Rosiclare sandstone and the Renault formation in Western Kentucky and the adjacent part of southern Illinois." Although the Levias member crops out in several places near Levias, particularly in the southern part of the Dike-Eaton area, the nearest complete section of the Levias is in a quarry about 5.7 airline miles northeast of Levias. This quarry is about 300 feet northeast of Kentucky Highway 91, at a point about 3½ miles by road northwest of the center of Marion, and is shown on the Marion 7½-minute quadrangle.

Overlying the Meramec series is a sequence of alternating shale, limestone, and sandstone formations of the Chester series. Except for the hill in the southern part of the Dike-Eaton area where the Renault formation and the Bethel sandstone crop out, most of the Chester series is northwest of the Levias fault in the Levias-Keystone area.

The lowest formation of the Chester series is the Renault formation, which is about 70 feet thick and crops out in the southern part of the Dike-Eaton area. In the mapped areas, the formation can be divided into three lithologic units: the upper and lower units being dominantly limestone and the middle unit being dominantly shale. The lower and middle units seem to correspond to the Shetlerville member of Weller (1921, p. 27) and the upper unit to the Downeys Bluff member of Atherton (1948) according to Weller and others (1952, p. 62, 63).

The lower unit of the Renault formation is about 25 feet thick and is medium-gray fine-grained argillaceous limestone. Rarely the beds are oolitic, and some contain a few shaly partings; the lowest few feet of this unit is very sandy limestone. The middle unit is about 20 feet thick and is dominantly a dark calcareous shale interbedded with limestone. The upper unit is 25 feet thick and is medium- and light-gray fine- and medium-grained limestone that contains some shaly partings and a few thin gray-green shale beds; some of the limestone is oolitic.

Overlying the Renault formation are the Bethel sandstone, Paint Creek shale, and Cypress sandstone. Because of the difficulty in distinguishing the Bethel and Cypress sandstones and the scarcity of information on the formations in this area, the Bethel, Paint Creek, and Cypress are undifferentiated on plate 1. In the southern part of the Dike-Eaton area, however, where only the lowest 20 feet of this undifferentiated unit crops out, it is shown as the Bethel sandstone; and in the southwestern part of the Levias-Keystone area where only the upper part crops out, it is shown as the Cypress sandstone.

The undifferentiated Cypress, Paint Creek, and Bethel is about 150 feet thick and consists dominantly of light- and medium-gray fine- and medium-grained sandstone and some beds of gray sandy shale. The available data on these formations are from drill holes in the central part of the Levias-Keystone area (pl. 1, section *B–B′*).

Overlying the Cypress sandstone is the Golconda formation. Because it is dominantly shaly, no good outcrops of the Golconda were found in the areas, except north of the LaRue shaft in the southern part of the Levias-Keystone area. Two other large areas shown as Golconda on plate 1 are based either on data from drill holes or underground workings. The drill holes show that the Golconda formation is about 140 feet thick and consists dominantly of calcareous and sandy shales interbedded with dark coarse-grained limestone; the upper 35 feet of the formation is dominantly limestone interbedded with shale.

Overlying the Golconda formation is the Hardinsburg sandstone. Little information is available on the Hardinsburg in the mapped area, as drill holes have penetrated only parts of the formation and outcrops are few. Several drill holes, which are no more than 1½ miles northeast of the Levias-Keystone area, however, show that the Hardinsburg consists of two zones of massive and mostly fine grained sandstone and two zones of sandy shale (pl. 4) that total about 125 feet in thickness.

The Glen Dean limestone overlies the Hardinsburg sandstone, but does not crop out in the mapped area. On the basis of drill holes northeast of the Levias-Keystone area and outcrops about 3,000 feet northwest of the Keystone 3 shaft (pl. 1), the Glen Dean consists dominantly of light- and medium-gray limestone with a few beds of shale particularly near the top.

Overlying the Glen Dean limestone is the Tar Springs sandstone. Two small sandstone outcrops which may be the Tar Springs can be seen in road cuts along Kentucky Highway 297; one outcrop is on the northwest side of the Levias fault (pl. 1) and the other is on the east side of fault 8. The identification of these sandstones as the Tar Springs is based on an interpretation of data obtained from drill holes about 1,000 feet northeast of Kentucky Highway 297. In these drill holes, the Tar Springs sandstone consists dominantly of sandy shale and only a few thin beds of fine-grained sandstone.

IGNEOUS ROCKS

A lamprophyre dike occurs in the Dike fault in the Dike-Eaton area, and is known from mine workings and drill holes to extend through the mapped area southeast of U.S. Highway 60, and for at least 1,000 feet northwest of that Highway. As no dike crops out or is cut by drill holes in the extreme northwest end of the Dike-Eaton area or in the Levias-Keystone area, the northwestward extent of the dike and its relation to the Levias fault are unknown. The southeastern part of the dike is mapped and described by Thurston and Hardin (1954, p. 91).

The dike trends about N. 20° W. and dips about 80° to 85° SW. Faults and associated calcite, fluorite, sphalerite, and galena are present within the dike or at the contact of the dike with the country rock. In the drill holes, the contact of the dike and the limestone is sharp and generally smooth, although locally irregular. The limestone walls are slightly marbleized as much as 5 feet from the dike.

Throughout most of the area, the dike averages about 10 feet in thickness and has a few offshoots less than 1 foot thick in the hanging wall; slivers of limestone locally are present within the dike. Near the southeast end of the Dike-Eaton area, the dike splits into three parts which are 5, 7, and 3 feet thick associated with dikelets that are less than 1 foot thick (Starnes, 1950, p. 17, U.S.B.M. DDH 50).

Megascopically, the dike is a sugary-textured dark-gray or greenish-gray dolomitic rock that contains abundant pyrite and small plates and books of dark-reddish-brown mica. The rock weathers readily to a brownish-yellow mica-bearing residuum.

A petrographic examination of the dike rock was made by Jewell J. Glass (written communication, May 3, 1943) of the Geological Survey. The dike rock was found to be greatly altered lamprophyre in which the only remaining original mineral is pale-reddish-brown biotite. Fringes of serpentine and chlorite around biotite are common. Crystals of olivine and pyroxene are replaced largely by carbonate. Grains of black opaque material probably represent altered magnetite.

STRUCTURE

The Levias fault system (Levias fault and faults 1 to 9) consists of two northeastward-trending faults and an intervening area 300 to 1,000 feet wide that is underlain by complexly faulted rocks. The Dike-Eaton fault system consists of two subparallel faults, 450 to 750 feet apart, that trend about N. 20° W. and join the Levias fault system on the north. No evidence was found of the Dike-Eaton fault system northwest of the Levias fault system. The displacement in the Dike-Eaton fault system is less than 20 feet, but that on the Levias fault system is as much as 600 feet. The faults are normal and dip from 50° to 90° but generally dip 80° to 90°. According to Weller and Sutton (1951) the Levias fault system continues for about 2.5 miles southwest of the mapped area. It also continues northeast of the mapped area, where it trends a little more northward and is called the Crittenden Springs fault system. Weller and Sutton (1951) show that the Dike-Eaton fault system ends against the Moore Hill fault system on the southeast, a few hundred feet beyond the area mapped herein. According to Thurston and Hardin (1954, pl. 12) the Eaton fault ends against the Moore Hill fault, but the lamprophyre dike along the Dike fault extends southeastward beyond the Moore Hill fault.

Geologic data for mapping the faults were obtained from several sources: underground workings that cut or follow the faults; diamond-drill holes that cut the faults; exposures of fault surfaces or veins that are rarely at the surface, but are more commonly in the walls of caved pits or shafts; and outcrops or large boulders of brecciated and silicified sandstone ("quartzite reefs"). Stratigraphic studies that indicated juxtaposition of formations not in normal sequence also disclosed the presence of faults.

The Levias fault, which bounds the Levias fault system on the southeast in the Levias-Keystone area, does not crop out; however, steeply dipping Tar Springs(?) sandstone near the fault is exposed in a road cut on Kentucky Highway 297. The general strike of this fault is N. 30° E. and the dip is 85° to 90° NW.; the downthrown side is on the northwest throughout its extent; and the displacement is as muct as 600 feet. On the footwall side, the Ste. Genevieve limestone appears to be nearly horizontal except within about 100 feet of the fault, where it has been drag folded and may dip steeply northwestward. Much of the production from the areas has been from this fault.

Fault 1, which bounds the Levias fault system on the northwest, strikes N. 30° to 40° E. and is vertical or dips steeply northwest. At the surface the hanging wall of fault 1, as well as that of the whole Levias fault system, is mainly in the Hardinsburg and Cypress sandstones, which dip 10° to 45° SE. within 200 to 300 feet of fault 1. Farther northwest of fault 1, the dip is reversed, and the beds generally dip 10° to 15° NW.

Fault 1 has been cut in several shafts and pits in the southern part of the Levias-Keystone area. In the central part of the area, the fault was intersected by USBM DDH 87 and by an underground drill hole from the 300 level of the Keystone 4 shaft. The displacement lessens to the north as a result of cross faulting. The maximum displacement along fault 1 is probably 200 feet.

Fault 2, near the north end of the Levias-Keystone area, trends N. 85° E. and is known only from unmapped workings of the Keystone mine (G. C. Hardin, Jr., written communication, 1945). Displacement at the surface is less than 50 feet.

Fault 3 trends about N. 30° E. and dips 60° SE. The fault was cut at about 165 feet in the Chipps shaft, where medium- to dark-gray limestone of the Golconda formation probably constitutes both walls of the fault. Displacement is probably no more than 25 feet; the downthrow is to the southeast.

Fault 4 trends N. 37° E., dips about 80° NW, and the downthrow is to the northwest. The displacement is probably no more than 50 feet. The fault is known only in the 210 level of the Chipps shaft (pl. 2) where the walls are the Cypress sandstone and the Golconda formation. The results of drag folding of beds along a fault are well illustrated between the Chipps shaft and the fault exposed on the 210 level, where the beds dip from 25° to 90° as the fault is approached.

Fault 4a does not reach the surface and is exposed only in the end of the 210 level of the Chipps shaft (pl. 2; pl. 1, section *A–A′*). The fault trends about N. 35° E. and dips about 60° NW. The walls of the fault, where cut on the 210 level, are the undifferentiated Cypress, Paint Creek, Bethel, and Renault formations; the displacement is between 150 and 200 feet, and the downthrow is to the northwest.

Fault 5 trends N. 60° to 75° E., and is vertical; it has been explored in workings from the Keystone 3 shaft. In effect, fault 5 offsets the Levias fault. A fault that trends in the same direction as the Levias fault continues southwest of fault 5, but the displacement is small and the fault apparently dies out. The major displacement follows fault 5 for about 300 feet southwestward and then continues along the southwestern segment of the Levias fault.

Fault 6 trends about N. 30° E. along most of its length, although the trend of the southwestern segment appears to be more northward. This fault dips 50° to 55° E. toward the Levias fault. The displacement along this fault, as shown on the 300 level of the Keystone 4 shaft (pl. 2), is about 100 feet. Fault 6 must join the Levias fault at no more than 50 feet below the 400 level of the Keystone 4 shaft, as the two faults are about 100 feet apart on the 300 level and about 35 feet apart on the 400 level.

Fault 7 trends about N. 40° to 50° E. and probably dips steeply northwestward (pl. 1, section *B–B′*). The fault was cut in USBM DDH 85 (Starnes, 1947, p. 8) and in Price DDH 14, 15 and 17, although no core of the fault zone was obtained from the Price holes. The stratigraphy, as interpreted from the several drill holes in the area, indicates that the displacement is about 150 feet.

Fault 8, near the north end of the Levias-Keystone area, does not crop out in the mapped area. The presence and northward trend of this fault are suggested by drill-hole data and outcrops of the Golconda formation and Tar Springs sandstone, which are at about equal altitudes a few hundred feet northeast of Kentucky Highway 297. Presumably fault 8 joins the Levias fault on the 300 level of the Keystone mine (pl. 2), but the drift near the presumed junction is tightly lagged and no positive evidence of the junction could be seen.

Fault 9, a cross fault, trends about N. 20° W. Steeply dipping sandstone beds about 200 feet east of the Pope shaft suggest the presence of this fault.

Based on data from drill holes northeast of the mapped areas, several northeastward-trending faults of small displacement may be present in the northern part of the Levias-Keystone area—between the Levias fault and fault 8.

The Eaton fault trends about N. 20° W. and is nearly vertical. The fault was traced throughout the mapped area to within 300 feet of the presumed junction with the Levias fault system on the basis of exposures in a series of pits, shafts, opencuts, and intersections in three diamond-drill holes.

Through most of the mapped area, no measurable vertical displacement on the Eaton fault could be found. In the northwestern part of the Dike-Eaton area, however, the altitudes of the Rosiclare sandstone member of the Ste. Genevieve limestone in diamond-drill hole 63, and in outcrops along the road between Midway and Levias suggest vertical displacement of as much as 5 feet. Horizontal displacement of unknown although probably small amount is suggested in the 50 level of the Jennings shaft, where G. C. Hardin, Jr., reports that horizontal slickensides are present on the fault's west wall, which is composed of flat-lying oolitic beds of the Fredonia limestone member.

J. S. Frazer, who has done considerable mining along the Eaton fault, reports (oral communication, April 1943) that the vertical displacement of the base of the Rosiclare sandstone member is slight, probably not exceeding 5 feet, and that horizontal slickensides are present in now inaccessible workings.

The Dike fault trends about N. 20° W. and dips 80° to 85° SW.; the downthrown side is to the southwest. The fault was traced by a series of pits, shafts, and six diamond-drill holes (pl. 1). Based on the data from the five diamond-drill holes nearest U.S. Highway 60, vertical displacement of as much as 20 feet is present along the Dike fault. To the southeast, the displacement appears to die out. No evidence of horizontal displacement was found except in the Gilless mine, where horizontal slickensides were noted along a fracture within the fluorspar.

The actual fracturing and associated vein minerals along the Dike fault may lie on either side of or within the dike. For example, in most of the diamond-drill holes (Starnes, 1950) and on most of the 90 level of the Gilless mine (pl. 3), the fault and associated minerals are within the dike, whereas at the north end of the Gilless 90 level and in the Settles mine the fault and associated minerals are between the dike and limestone country rock.

The general attitude of the beds in the block of ground southeast of U.S. Highway 60 and between the Dike and Eaton faults is N. 30° W., 1° NE. This attitude is based on the altitude of the base of the Rosiclare sandstone member in U.S.B.M. DDH 50, 56, 63, and 64. Reconnaissance examination of the Rosiclare for about 1 mile northeast and 1 mile southwest of the Dike-Eaton area shows a similar regional dip of the block of ground between the Levias and Moore Hill fault systems.

The displacement along the Dike-Eaton fault system appears to be greater near the Levias and Moore Hill fault systems. This difference is probably a result of a dragging effect of the Moore Hill and Levias fault systems that was greater on the small rectangular block between the Dike and Eaton faults than on the larger unfaulted areas to the northeast and southwest. In the northern part of the Dike-Eaton area, the block between the Dike and Eaton faults has dropped about 20 feet along the Dike fault. In the central and southern parts, the vertical displacement is virtually zero. According to Thurston and Hardin (1954, pl. 12), however, the beds have a vertical displacement of about 5 feet near the south ends of these faults as the Moore Hill fault system is approached.

ORE DEPOSITS

More than 200,000 tons of crude fluorspar ore probably has been produced from mines in the area; most of this ore has come from the Levias-Keystone area. Of this total, only about 25,000 tons of crude ore has been produced from the shallow mines along the Dike and Eaton faults, as these mines have narrower veins and higher zinc content than veins in the Levias-Keystone area. Both before and during World War II zinc was considered detrimental in these ores because of the scarcity of selective flotation mills in the Kentucky district.

The ore consists principally of fluorite and minor amounts of sphalerite, galena, barite, and quartz, in a matrix of calcite and limestone breccia. The crude ore ranged from 50 to 90 percent CaF_2 and commonly averaged 60 percent CaF_2. Most of the ore mined was marketed as metallurgical grade (about 85 percent CaF_2) after log washing or jigging.

Most of the ore produced has been from veins, although large quantities of gravel fluorspar have been mined, particularly from the Dike-Eaton area. Gravel fluorspar is the fluorspar which has been concentrated in a clay matrix in the overburden by weathering and removal of the calcite of the vein and the limestone wallrock. The term also is used to include the fluorspar in weathered vein zones for varying distances below the overburden. Along the Moore Hill fault system nearby this type of "soft" ore between "hard" walls is known to extend to depths of 250 feet at the Nancy Hanks mine (Thurston and Hardin, 1954, p. 102).

The veins are localized along, and are younger than, the faults. The veins also are younger than the lamprophyre dike, because: (a) they cut the dike locally, (b) remnants of dike material are found within the mineralized zone, and (c) some of the premineralization fault gouge is composed of dike material.

MINERALOGY

The fluorspar deposits of the areas, particularly those along the Levias-Keystone fault system, contain very few minerials. Minerals found along this system, for example in the Keystone mine, are fluorite, calcite galena, and quartz. In addition to these, sphalerite, barite, pyromorphite, smithsonite, and greenockite were observed along the Dike-Eaton fault system.

Fluorite.—The most abundant and important mineral produced from the areas is fluorite. Most of the fluorite is coarsely crystalline and is brown, white, or purple. In the thicker veins, the fluorite is brown and white; in the narrower veins and parts containing sphalerite it is commonly purple, and generally is finer grained than the brown and white varieties. Crystal clusters in vug fillings are relatively uncommon.

Sphalerite.—The second most important ore mineral present is sphalerite, which occurs in the Dike-Easton area. It is found as light-reddish-brown veinlets and finely disseminated masses in the fluorite and calcite. The light color of the sphalerite suggests a low iron content.

Galena.—A small quantity of steel-gray galena is present in the Dike-Eaton area and to an even lesser extent in the Levias-Keystone area. The galena occurs as small crystals and crystals clusters in streaks or is disseminated through the fluorite and calcite.

Calcite.—Massive white and gray coarsely crystalline calcite is the most common gangue mineral in the veins. Individual calcite crystals are uncommon.

Quartz.—A few light-gray and transparent tiny quartz crystals are in the veins, and a few crystals of smoky quartz as much as 0.2 inch in diameter have been found in fissures in the wallrocks of the veins.

Barite.—Small quantities of white massive and bladed barite are commonly but irregularly disseminated in the veins along the Dike fault and in the overlying gravel fluorspar, in masses as much as 2 inches in diameter.

Alteration products.—The alteration products that were identified are smithsonite, pyromorphite, and greenockite; others are probably present, especially in the overlying gravel fluorspar. Smithsonite occurs as brown crystalline botryoidal coating that encrust small vugs in the gravel fluorspar masses. In the gravel fiuorspar zone pea-green pyromorphite occurs with galena, and greenish-yellow greenockite with smithsonite.

VEINS, ORE BODIES, AND WALLROCKS

The fluorspar veins in the area are fissure fillings and in part replacement deposits along the faults. The veins range in thickness from less than 1 inch to 25 feet. The minable veins are consistently thicker along the Levias-Keystone fault system (commonly 4 to 8 feet) than along the Dike-Eaton fault system (commonly 2 to 3 feet). The thickest vein in the Dike-Eaton area is about 7 feet, whereas a vein along fault 6 in the Keystone mine is 25 feet thick. The veins are less variable in thickness, however, in the Dike-Eaton area than in the Levias-Keystone area.

The composition of the veins ranges from almost entirely fluorite to entirely calcite, although both minerals generally are present. The common type of ore contains a little over 60 percent fluorite; the rest is largely calcite. The calcite content of the Dike-Eaton veins generally is less than that of the Levias-Keystone veins. Sphalerite and galena occur mostly as disseminated grains and as streaks in calcite and fluorite, commonly near the edges of the veins.

Although the Levias-Keystone veins contain little or no sphalerite and only traces of galena, the Dike-Eaton veins contain as much as 8 precent zinc (averaging 2 to 3 percent) and nearly 1 percent lead. A spatial relation between dikes and veins containing sphalerite also is present elsewhere in the fluorspar district, for example at the Hutson, Old Jim, Commodore, and Hickory Cane mines (Osterling, 1952; Ulrich and Smith, 1905; Trace, 1954). The silica content of the ore averages 5 to 10 percent.

In general, the contacts of the veins are sharp, although in places a zone of limestone breccia containing fluorite and calcite grades into virtually unmineralized limestone.

Shaly gouge as much as 2 feet thick is present in some of the veins. Along the Dike fault the gouge is commonly composed of altered dike material which may be present within the vein and along its edges.

The evidence suggests that most of the fluorite is a fissure filling, but that some is a replacement of calcite and, to a small degree, a replacement of the limestone wallrock. Fluorite that replaces calcite has been observed in places in the Keystone mine. Where most of the vein in this mine is calcite, the fluorite occurs in seams and veinlets invading the calcite. Where the calcite-fluorite ratio is about 1:1 or less, the calcite forms irregularly embayed masses surrounded by a matrix of coarse-grained fluorite. Elsewhere, the vein is almost entirely fluorite, and may be the result of nearly complete replacement or fissure filling.

Faulting that is later than the fluorite-calcite deposition is indicated by the brecciation, sheeting, and slickensiding of these minerals. Deposition of sphalerite and galena, commonly in these broken zones near the edges of the veins, suggests that these sulfide minerals in general are younger than the calcite and fluorite here.

In addition to the vein deposits, one of the types of "mixed deposits" (Weller and others, 1952, p. 30–31) may be present along the Eaton fault. A mixed deposit may consist of a horizontal bedded or replacement ore body, typical of the Cave in Rock deposits in Illinois, and a steeply dipping vein deposit. The possible presence of such a mixed deposit is based on reports that in places the best ore along the Eaton vein was found directly beneath the Rosiclare sandstone member, where the ore locally widened from 2–3 to 6–7 feet within a vertical range of 5–10 feet.

Some of the fluorspar mined, particularly that from the Dike-Eaton area, was gravel fluorspar. According to local sources, only a small quantity of the ore mined from the Levias-Keystone area was gravel fluorspar, but perhaps one-third to one-half of the Dike-Eaton ore was of this type.

Thicknesses of veins mined in the areas ranged from 1½ to 25 feet; deposits in the Keystone mine generally are 4 to 8 feet thick, and in the Dike-Eaton area, 2 to 3 feet thick. Some of the ore shoots in the Keystone mine are as much as 1,000 feet long and have been mined to a depth of 500 feet, although the average ore shoot is smaller. Along the Dike-Eaton fault system, the typical ore body mined is 100 to 150 feet long and the deepest working is about 150 feet (fig. 2; pl. 3).

The wallrocks in the Levias-Keystone area are limestone, sandstone, and shale of the Chester and Meramec series, and in the Dike-Eaton area they are the St. Louis and Ste. Genevieve limestone of the Meramec series, and a lamprophyre dike.

Where examined in the Keystone mine, the wallrocks include the Hardinsburg(?), Golconda, Cypress, Paint Creek, Bethel, Renault, Ste. Genevieve, and St. Louis formations. Generally the limestone walls are silicified to varying degrees 10 to 30 feet from the vein; they are commonly brecciated, drag folded (pl. 24, 210 level of Chipps shaft), and contain many calcite and fluorite veinlets. The contacts of the sandstone walls with the veins are sharp, and similarly the walls are generally brecciated and silicified, although to a lesser degree than the limestone walls, and contain abundant calcite and fluorite veinlets.

The lamprophyre dike along the Dike fault is altered to a light greenish gray and is commonly much sheared and broken where it is a wall of the vein. In places where both walls of the Dike vein are composed of dike rock, the vein cuts across from one side of the dike to the other. In other places the vein is along the contact of the dike and limestone. The walls of the Dike and Eaton veins show little or no drag folding, in contrast to the strong drag folding of the beds in the Levias-Keystone area.

LOCALIZATION OF DEPOSITS

The deposits in the areas are localized along faults, and possibly to a minor extent in bedded-ore offshoots of the Eaton vein. Basic to the problem of localization is the fact that the veins contain varying quantities of calcite and fluorite. The thick veins of the Keystone range from almost all fluorite to all massive calcite; generally calcite is a common and abundant mineral. In contrast, the persistent but narrow veins along the Dike-Eaton system commonly contain calcite, but apparently much less in proportion to fluorite than veins of the Levias-Keystone area. No geologic clues are known to the writer that will predict the calcite-fluorite ratio of a given vein.

The problems of most concern to mining geologists of the district are the location of the faults and the vertical and horizontal positions within these faults that are most favorable for veins of minable thickness. Generally speaking, this problem is far from solved, although certain factors described below are used to guide exploration. In many places these factors seem to explain reasonably the position of the veins within the faults.

For descriptive purposes, the causes for localization of the deposits may be divided into factors of both stratigraphic and structural control.

The stratigraphy of the wallrocks may exercise considerable control over the thickness of the vein. Most of the ore from the mapped areas has been mined from veins where at least one wall and generally both are the St. Louis and Ste. Genevieve limestones, Renault formation, and Bethel sandstone. Little or no ore has been found where both walls of the faults are in rock above the Bethel—possibly because the Bethel and older formations are dominantly competent and massive in contrast to the post-Bethel formations which contain many beds of incompetent shale, siltstone, and thin-bedded sandstone. Therefore openings formed by faulting where the walls are of Bethel sandstone or older would be expected to remain open for vein filling, and incompetent shaly material would less likely be dragged into the fault zone.

The structural factors possibly affecting the localization of the deposits are the change in dip along the faults, and the amount of displacement.

The relation of change in dip of the fault to localization of ore deposits is seen in the Gilless mine (pl. 3); the vein widens where it is nearly vertical and becomes somewhat narrower where it dips about 75°. This change might reflect the wider opening created along the steeper part of a normal fault.

The displacements are generally greater (as much as 600 feet) along the Levias fault and fault 6 than along other faults in the vicinity, and they have also produced the largest quantity of ore. Narrow but locally minable deposits have been worked in the Dike-Eaton area, however, where the displacement ranges from less than a foot to 20 feet.

Another possible factor of ore localization which is apparently unrelated to those given above may be present along the Dike fault zone. In the Riggs shaft, about 600 feet south of the south edge of the mapped area, ore has been mined from the dike where it is a single body about 10 feet thick. Near the southern edge of the mapped area, however, the dike has split into three separate dikes, 5, 7, and 3 feet thick, and vein minerals are virtually absent. This relation also exists 200 to 400 feet south of the Dike-Eaton area where USBM DDH 48 and 49 were drilled (Thurston and Hardin, 1954).

MINES AND PROSPECTS

The following information on the mines and prospects is based on direct observation, wherever possible, during 1942–45. Because few of the underground workings in the Levias-Keystone and Dike-Eaton areas were accessible during this period, some details of the workings were obtained from the mine records and conversations with operators.

Many data on individual properties and results of drilling by the U.S. Bureau of Mines in the Dike-Eaton and Price areas are given by Starnes (1947; 1950), who acquired his information during 1942–45 in cooperation with the Geological Survey.

EATON FAULT

OLD STANDARD MINE AREA

Little is known about past mining operations in the southernmost half mile of the mapped length of the Eaton fault (pl. 1). Ulrich and Smith (1905, pl. VIII) show the Manley or Miller and Lucky Star shafts in this area, but give no description. Currier (1923, p. 100) also mentions the Old Standard mine and the minerals as calcite, fluorite, galena, and sphalerite. None of these shafts is now identifiable.

LA RUE BROTHERS AREA

The La Rue Brothers area includes about 1,200 feet along the Eaton fault extending southeast from the La Rue shaft. Ulrich and Smith (1905, pl. VIII) show the "LaRue Heirs prospect" but give no description of it. As shown on plate 1 of this report, nearly the entire length of the Eaton fault has been prospected to shallow depths. Veins commonly are reported to be from 1 to 3 feet thick; locally, the thickness increases to 5 feet in the top part of the Fredonia limestone member.

The La Rue shaft was sunk in 1943 to a depth of 60 feet, and a level was driven about 50 feet southeast along the Eaton fault (Starnes, 1950, p. 14). The vein was nearly vertical and averaged 6 inches to 2 feet in thickness between limestone walls; in a small pocket it widened to 5 feet. The ore is estimated to contain more than 60 percent fluorite, at least 5 percent sphalerite, and minor amounts of galena. Three holes drilled by the Bureau of Mines in 1944 (Starnes, 1950) cut the fault near the base of the middle unit of the Fredonia; limestone member of the Ste. Genevieve limestone; only traces of ore were found.

CONYER (JENNINGS LEASE) AREA

In the Conyer area, extending abount 1,100 feet southeastward from U.S. Highway 60 nearly to the La Rue shaft, gravel fluorspar was mined from several opencuts. These workings are probably the same as noted by Ulrich and Smith (1905, pl. VIII) as the Eaton mine, where mining was first done in the Dike-Eaton area. Several shallow shafts have been sunk to depths of 30 to 50 feet since 1900, and narrow ore bodies were found. Judging from the material now on the dumps, the ore contained a large amount of sphalerite.

In November 1943 the Jennings shaft was sunk to a depth of 45 feet and later was examined by G. C. Hardin, Jr. The ore was 15 to 18 inches thick and consisted of brown and white fluorite with vertical streaks of galena. A 1-inch layer of sphalerite-bearing fluorspar is present near the west wall of the vein. The vein is almost vertical, and its contact with the oolitic limestone walls is sharp. Horizontal slickensides on the west wall of the vein, and the undragged horizontal beds suggest only horizontal movement along the fault.

Later work in the Jennings shaft is summarized by Starnes (1950, p. 15), who reports that the shaft was sunk to 90 feet and that the vein was 6 feet thick.

M. J. FRANKLIN AREA

Small amounts of fluorspar have been mined from depths of less than 70 feet in the M. J. Franklin area between U.S. Highway 60 and the intersection of the Eaton fault with the Levias fault. Ulrich and Smith (1905, pl. VIII) show a Mary Franklin prospect in this area, but give no description. The ore is reported by local miners to average about 20 inches in thickness and to contain fluorite and some sphalerite and galena.

A shaft with a large dump that contains fluorspar is about 325 feet south of the intersection of the Eaton and Levias faults (pl. 1). No information could be obtained about this shaft. Obviously the workings had cut a vein, although the shaft is more than 100 feet west of the trend of the Eaton vein as shown on plate 1. Either a long crosscut was dug to the east or perhaps the Eaton fault near its junction with the Levias fault curves more to the west from its original trend of N. 20° W.

DIKE FAULT

HENLEY AND ELI BROWN PROPERTY

Approximately the southernmost 300 feet of the mapped Dike fault is part of the Eli Brown property, which has been described by Thurston and Hardin (1954) and Starnes (1950).

The adjoining 1,500–1,600 feet along the Dike fault is on the Henley property. It is reported that the Frazer shaft (pl. 1) is 100 feet deep, and that about 100 tons of ore has been mined from a 2-foot vein of fluorspar, calcite, and sphalerite (J. S. Frazer, oral communication, 1943). The dump rock from this shaft contains abundant purple, white, and brown fluorite; purple fluorite is most common. Galena occurs as veinlets in the fluorite along with veinlets and disseminations of sphalerite; calcite is notably uncommon. Some specimens of the dump material are dominantly reddish sphalerite containing cubes of galena, that have faces 1/8 to 1/2 inch across, in a matrix of white fluorite.

The Walker shafts (pl. 1) are reported to be 30 to 50 feet deep (Starnes, 1950, p. 9).

CONYER (JENNINGS LEASE) AREA

Several shafts have been sunk and considerable fluorspar has been mined from the Conyer area (Starnes, 1950, p. 1, 10). The Joiner shaft is about 100 feet deep; stopes extend north and south of the shaft (fig. 2). The Jennings 1 and 2 shafts are 100 and 140 feet

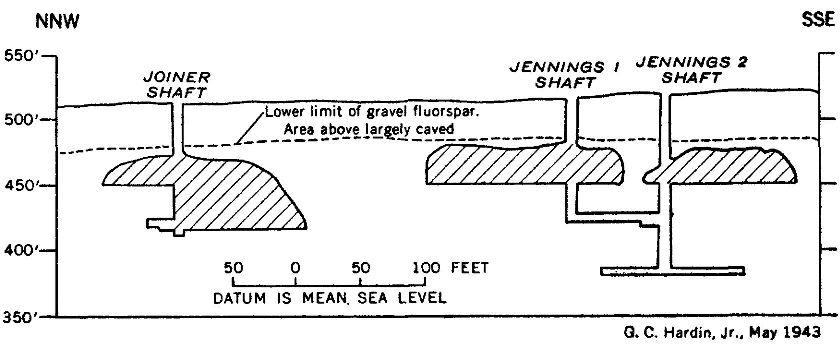

FIGURE 2.—Longitudinal section along part of Dike vein, showing extent of mined areas.

deep, respectively, and are connected on the 100 level, where the ore averages about 4 feet in thickness and is more than 60 percent fluorite and about 7 percent zinc. The ore stoped above the 70 level is reported to average about 3 1/2 feet in thickness.

The Belt shaft (Jennings 3 shaft) of Starnes (1950) is reported to be 60 feet deep. The Jennings 4 shaft, 150 feet deep, has a level at 108 feet. The shaft was examined by Starnes (1950, p. 10), who reports that a drift was extended 145 feet northwest and 142 feet southeast of the shaft, and a thin ore body was mined above most of the drift.

The U.S. Bureau of Mines drilled holes 64, 65, and 66 in 1944 (pl. 1), and all three holes cut narrow veins of fluorspar that contain some sphalerite (Starnes, 1950). According to Geological Survey logs of these holes, the vein was cut at a depth where the country rock is the lower unit of the Fredonia limestone member of the Ste. Genevieve limestone in holes 64 and 65, and is the St. Louis limestone in hole 66. In holes 64 and 66 the veins are in narrow slivers of limestone within the dike.

GILLESS PROPERTY

The Gilless property includes about 700 feet of the Dike fault south of U.S. Highway 60. The vein has been explored by several shallow shafts and pits to depths of 50 feet. Some gravel fluorspar has been produced, but most of the mining has been done from the Gilless shaft.

The Gilless shaft is 123 feet deep with levels at 70 and 90 feet (pl. 3). The level at 70 feet had been driven 105 feet southeast and 75 feet northwest when it was examined in early 1943. The average vein thickness is about 3½ feet, although it is somewhat narrower at the southeast and northwest faces of the drift. In the southeast face, the vein is composed of fluorite mixed with calcite, limestone, and considerable sphalerite. In the northwest face the vein pinches to 6 inches at the top of the drift, but is about 2½ feet thick in the floor of the drift. A channel sample representing a thickness of 2 feet from the northwest face contains 80 percent fluorite, and a 28-inch sample from the southeast face contains 64 percent fluorite.[1] Assays were not made for zinc or lead.

The southeast face of the 70 level previously had been examined when the face was about 60 feet southeast of the Gilless shaft (pl. 3, inset), and the following description applies to this location. The east wall of the vein is vertical and is bounded by lamprophyre dike rock. The vein is about 4 feet thick and is divided into three parts for descriptive purposes. For about 14 inches from the dike, the eastern part of the vein is composed of light-brown massive fluorite which is slightly sheared. Sphalerite stringers comprise about 5 percent of this part of the vein and are particularly common near the

[1] Analyst: C. L. Frazer, Marion, Ky.

dike. Small clusters of galena crystals, commonly cubes, and small quantities of barite are scattered through the fluorite.

The central part of the vein is 13 inches thick and is separated from the eastern and western parts by a thin seam of shaly gouge. The central part of the vein is composed chiefly of calcite and fluorite; the fluorite is brown with some purple streaks and comprises about 40 percent of this part. Some sphalerite, galena, and a little barite are present.

The western part of the vein is 18 inches thick and is composed of limestone breccia in a matrix of calcite and fluorite; the fluorite makes up about 20 percent of this part. The western part grades into limestone on the west wall of the drift; sphalerite stringers are numerous along the west wall, and along the east wall next to the dike.

The 90 level of the Gilless shaft, as of February 1945, was driven about 275 feet northeast and 200 feet southwest of the shaft (pl. 3). The vein in the drift ranges from 1 to 5 feet in thickness, and in the stopes it is as much as 6½ feet thick. The dip of the vein ranges from 75° W. to vertical. The vein is between dike walls in the drift except near the northeast end where it is between the dike and the Fredonia limestone member.

Much of the vein above the 90 level southeast of the Gilless shaft has been stoped; to the northwest the ore was too narrow for stoping except along the northwesternmost 90 feet, where a vein averaging about 2 feet in thickness was stoped for a short distance above the drift.

The fluorspar vein on the 90 level consists of about 60 percent brown, massive, and intensely fractured fluorite; most of the rest of the vein is composed of calcite and slivers of dike rock. The vein also contains as much as 5 percent sphalerite and 2 percent galena. Small quantities of smithsonite, barite, greenockite, and smoky quartz crystals were found on the dump of the Gilless shaft, although they were not noted underground.

The lamprophyre dike in this area is as much as 10 feet thick. The dike has been altered and is light green and soft within 2 feet of the vein. More than 2 feet from the vein, however, the dike is hard and dark greenish gray to black.

The U.S. Bureau of Mines drilled holes 60 and 63 (Starnes, 1950) on the Gilless property. A 3-foot vein of fluorspar within the dike was cut in hole 60 according to the Geological Survey log; both walls of the dike are St. Louis limestone. Hole 63 cut the fault where both walls of the dike are the lower unit of the Fredonia limestone member of the Ste. Genevieve. A few veinlets of fluorite were found within the dike in this drill hole.

M. J. FRANKLIN AREA

Along the Dike fault for about 900 feet northwest of U.S. Highway 60, many shallow shafts and pits have been dug, mainly for gravel fluorspar. The Settles shaft was sunk 70 feet in December 1943, and the level was driven northwest about 50 feet and southeast about 50 feet. On the 70 level the vein appears to be a fissure filling between the flat-lying Fredonia limestone member on the west and the lamprophyre dike, which has been altered to light green, on the east. The vein ranges in thickness from 1½ to 3 feet and dips 80° to 85° SW. In the floor of the drift it averages nearly 2 feet in thickness. The fluorite is brown and purple and contains as much as 10 percent sphalerite and some galena. The vein was stoped for about 10 to 20 feet above the entire 100-foot length of the drift.

FAULT 1 (POPE AND LA RUE SHAFTS)

Along fault 1 (pl. 1), the Pope and La Rue shafts have yielded only a few tons of fluorspar. No workings in this area were accessible, and little information about them is available.

According to Mark Conyer, former superintendent for the Pope Mining Co., the Pope shaft was sunk to a depth of 240 feet in the footwall of fault 1, and crosscuts were driven to the vein on the 70, 180, and 240 levels. The vein was 4 feet thick at the 70 level, but thickened to 10 feet at the 240 level. The fault dips about 85° NW. A drift was driven 60 feet southwest and 60 feet northeast on the 240 level. Only about 1 ton of fluorspar was mined, however, as the vein consisted primarily of calcite and only a small amount of fluorite. A drift was driven 90 feet southwest and 70 feet northeast on the 70 level, but the vein was mostly calcite.

PRICE AREA

The Price area includes the area north and northeast of the junction of the Levias-Keystone fault system with the Dike-Eaton fault system (pl. 1). No ore has been produced from the area.

A prospect shaft south of the Levias fault, sunk about 1934, is reported to be about 110 feet deep in steeply dipping limestone and sandstone. According to Starnes (1947), no ore was found.

Eighteen holes (Price 1 to 18) were core-drilled by the Hillside Fluor Spar Mines in 1942–43 (pl. 1). Holes 6 and 16 are not shown, as their location is uncertain. No ore was found; however, the bedrock in the area was deeply weathered and broken so that core recovery was poor. The U.S. Bureau of Mines also drilled three holes USBM DDH 82, 85, 87) in the area in 1944 (Starnes, 1947) without finding ore.

KEYSTONE AREA

The Keystone area has been one of the most productive parts of the Kentucky fluorspar district. Over 150,000 tons of ore had been produced from this area as of 1945 (Starnes, 1947, p. 1).

The Keystone mine (the Keystone 2, 3, and 4 shafts, pl. 1, 2) was opened in 1903 by the Keystone Mining and Mineral Co. (Ulrich and Smith, 1905, p. 205–206, Currier, 1923, p. 99–100). Production was intermittent until 1929, when the mine property was acquired by the Hillside Fluor Spar Mines. From 1929 to 1945 the mine was operated almost continuously.

The Keystone 2, 3, and 4 shafts have been worked to a depth of 500 feet along part of the Levias fault near shaft 2. Most of the ore has come from the Levias fault and fault 6, and was white and brown high-grade fluorspar. A small amount of purple fluorite is present in veinlets, but there is probably less in this mine than in most of the other large mines of the district. Calcite is the only gangue mineral found in large quantities. A small amount of galena also is present but no sphalerite was seen. The fluorspar vein was as thick as 25 feet along fault 6; more typical ore bodies, however, were 4 to 8 feet thick.

Underground geologic mapping on part of the 300 level of the Keystone mine was done by the Geological Survey before geologic work was discontinued in 1945. This level was mapped in detail for about 700 feet northeast of the Keystone 2 shaft and for about 750 feet mostly southwest of the Keystone 3 shaft (pl. 2). Additional reconnaissance mapping was done on the 300 level; the 210 level of the Chipps shaft was mapped also (pl. 2).

The best ore body noted in the mapping was on the 300 level near the Keystone 4 shaft (pl. 2). The ore body extended from near the northeast end of the drift along fault 6 to within 200 feet of the southwest end of the drift, a total of nearly 700 feet. Of this 700-foot length, the southwesternmost 300 feet contained high-grade massive fluorspar 15 to 20 feet thick. Through the rest of this 700-foot section, the ore was about 6 feet thick. The ore was stoped for about 50 feet above the 300 level. In the northeast and southwest faces of the level the vein was mostly calcite.

A brief examination was made of the veins along fault 6, and the Levias fault in a crosscut, and of short drifts from the Keystone 4 shaft at a depth of 400 feet. The two faults are about 35 feet apart with brecciated Ste. Genevieve limestone between them. On the 400 level the Levias fault is vertical, and fault 6 dips about 50° SE. as on the 300 level. The ore along both faults is as much as 20 feet thick and ranges in grade from 50 to 80 percent CaF_2.

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