Fluorspar Deposits in Western Kentucky

Part 2
Central part of the Commodore fault system
Crittenden County
Mineral Ridge area, Livingston and Crittenden Counties

GEOLOGICAL SURVEY BULLETIN 1012-C, D
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By ROBERT D. TRACE

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GEOLOGICAL SURVEY BULLETIN 1012-C, D

A detailed description of the geology and fluorspar deposits

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Central Part of the Commodore Fault System, Crittenden County

By ROBERT D. TRACE

FLUORSPAR DEPOSITS IN WESTERN KENTUCKY

GEOLOGICAL SURVEY BULLETIN 1012-C

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   Index map and longitudinal projection of fluorspar deposits of the central part of the Commodore fault system, Crittenden County, Ky. |

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FLUORSPAR DEPOSITS IN WESTERN KENTUCKY

CENTRAL PART OF THE COMMODORE FAULT SYSTEM, CRITTENDEN COUNTY

By Robert D. Trace

ABSTRACT

The central part of the Commodore fault system is in the western Kentucky fluorspar district, in Crittenden County, about 6 miles northwest of Marion. It has yielded from 30,000 to 40,000 tons of crude fluorspar and nearly 20,000 tons of zinc ore.

Limestones, sandstones, and shales of the Meramec, Chester, and Pottsville groups of Carboniferous age crop out as relatively flat-lying beds, except near faults. The rocks are transected by high-angle normal faults. The main faulted zone is the Commodore fault system, which displaces the beds from 1,500 to 2,000 feet.

The principal vein minerals are fluorite, calcite, smithsonite, sphalerite, and galena. Fluorite and smithsonite are the chief ore minerals, occurring as lenses along the faults.

The mines have been worked since 1892, but most of the workings are caved or filled with water.

INTRODUCTION

The central part of the Commodore fault system is in the northwestern part of Crittenden County, about 6 miles northwest of Marion and 1 or 2 miles northeast of Sheridan (fig. 2). The area can be reached from Marion by going 4 miles southwest on U. S. Highway 60, 3 miles northwest on Route 297 and northeast on a dirt road about a mile to the Bebout property. This dirt road approximately parallels the fault system (pl. 5). During extremely rainy seasons, parts of the dirt road are impassable.

According to Weller (1927, p. 100) the Commodore fault system is approximately 13 miles long, trends generally from N. 20° E. to N. 25° E., and extends southwest from near the Ohio River almost to the Crittenden-Livingston County line. In the area studied, however,
the general trend of the fault system is about N. 30° E. This report
deals only with the central part of the fault system, from the Bebout
and Lafayette properties on the south to and including most of the
Jenkins property on the north (pl. 5). The mapped area is rectangu-
lar, about 9,500 feet by 1,500 feet, elongate northeastward, and covers
approximately half a square mile.

Figure 2.—Index map of western Kentucky, showing location of the central part of the
Commodore fault system, Crittenden County, Ky.

The mines and prospects are in rolling hills of the Shawnee section
of the Interior Low Plateaus (Fenneman, 1938, p. 434-440). Dense
brush and a moderate growth of trees are common along the fault
system, which is bordered in part by cleared farm land. Altitudes in
the mapped area range from 415 feet above sea level north of Glen-
dale School to 560 feet near the Riggs shaft. Caney Fork, flowing
northwest toward the Ohio River, drains the area.

According to Fohs (1907, p. 214) the first prospecting or mining
along the central part of the Commodore fault system was done in
1892 at the Commodore mine. In 1905 Ulrich and Smith (1905, pl. 8) mentioned Franks prospect, and although the location is slightly different from that given by Fohs, it is probably on the Commodore property.

Fohs (1907, p. 38) states that the Glendale and Leona mines started work in 1901 and 1904, respectively, and Ulrich and Smith (1905, pl. 8) show the location of the Glendale and Terry prospects on an illustration. The names Glendale, Leona, and Terry probably refer to deposits on the Hickory Cane property.

Currier (1923, p. 106) describes mining operations on the K. K. property in 1920, and A. H. Reed, Sr., stated that mining was done on this property in 1916.

The first published mention of the Pasco property was by Jillson (1921, p. 172-175) in 1921; A. H. Reed, Sr., told the writer that the Pasco property was in operation at an earlier date. Jillson refers to the Glendale (Hickory Cane) and K. K. properties as being active, and the Commodore and Pasco properties as being inactive.

The Sullenger property is briefly mentioned by Currier (1923, p. 107). No mention of the Lafayette, Jenkins, and Bebout properties was found in the literature.

In October 1942 none of the mines or prospects in this area was being worked. Two shafts had been sunk in September 1942 on the north end of the Commodore property. The south end of the Hickory Cane property was worked from November 1941 to March 1942, and for a short period during 1944 and 1945. During late 1943, a lessee carried out a diamond-drilling program on the Jenkins property, but no mining was done. The Pasco and K. K. properties were operated for brief intervals during 1943 and 1945. A lessee sank the Riggs shaft on the Bebout property during 1945.

The earliest geologic report that deals with the Commodore area is by Ulrich and Smith (1905 pl. 8). Both the geology and ore deposits were mapped and described. Currier (1923, p. 106) briefly described the fluor spar deposits of the Commodore area and presented some data on the structure and igneous rocks.

The most detailed description of the geology of the Commodore area is by Weller (1927) and Weller and Sutton (1951). The writer has followed Weller's overall conception of the geology of the Commodore area, but has shown some differences by using a larger mapping scale.

As part of the wartime program of the U. S. Geological Survey for the investigation of strategic and critical minerals, field study of the central part of the Commodore fault system was started in October 1942 and continued intermittently until June 1945. Field work was under the general supervision of James Steele Williams and R. E. Van Alstine. H. J. Klepser, W. R. Thurston, G. C. Hardin, Jr.,
R. W. Lemke and D. A. Warner of the U. S. Geological Survey were associated with the writer in the field work. The major part of the field work consisted of studying the structure and stratigraphy from surface evidence, as only a few underground workings were accessible and they were in the zone of gravel spar. Brief underground studies were made at the Pasco and K. K. No. 2 shafts by the writer and at the Yandell shaft by D. A. Warner. The other shafts and pits were inaccessible because they were flooded or caved. Some underground data were obtained from three holes (diamond-drill holes 4, 5, and 6) drilled by the U. S. Bureau of Mines during the summer of 1945 (Starnes and Hickman, 1946). The writer also has incorporated into this report information based upon holes drilled by the Ozark-Mahoning Co. in 1947; the locations of the holes are not shown on the geologic map.

Because of the inaccessibility of most of the mine workings, the writer found that unpublished maps, drill logs, and reports of A. H. Reed, Sr., mining engineer of Marion, Ky., were of considerable assistance. Published and unpublished maps of Stuart Weller also have been of great value. Mine operators cooperated by permitting examination of accessible workings and volunteering information about past mining operations.

**GEOLOGY**

The geology and cross sections of the area are shown on plate 6. The accuracy of the interpretations on the geologic maps and cross sections probably varies considerably depending upon the proximity of surface outcrops, accessible underground workings, or diamond-drill holes.

**SEDIMENTARY ROCKS**

The sedimentary rocks of the fluorspar district of western Kentucky, described briefly in Chapter A by Williams and Duncan, consist of limestones, sandstones, and shales of the Meramec, Chester, and Pottsville groups of Carboniferous age. The Warsaw and Spergen limestones underlying these formations may have been penetrated in diamond-drill hole 1 (pl. 6, cross section C-C'). These two Mississippian formations consist of light to dark limestones (Weller, 1927, p. 10); the Spergen is oolitic in places. Typical cherty St. Louis limestone is present on the footwall of the Commodore fault system. The Ste. Genevieve limestone was penetrated in diamond-drill holes 7 and 8 (secs. G-G' and H-H'), but the absence of detailed drill logs precludes a more detailed description. The Rosiclare sandstone member has not been found in the central Commodore area.

The Renault limestone is believed to have been cut in several of the drill holes. The Cypress and Bethel sandstones and possibly the
Paint Creek shale were cut in some of the drill holes, and also are exposed on the surface. These formations are mapped as a unit, however, because of insufficient data regarding the Paint Creek shale. The Golconda limestone is exposed at a few places along the Commodore fault system but has not been found underground, either in a mine working or in a drill hole. Beds that probably represent the lower part of the Hardinsburg sandstone crop out at the Hickory Cane property and also on the south end of the Lafayette property.

The Palestine sandstone probably was cut by diamond-drill hole 7 (pl. 6, sec. G-G'). The sequence of Kinkaid limestone, Degonia sandstone, and Clore limestone is shown as one unit on the geologic map (pl. 6). In some of the cross sections of plate 6, this unit is divided into the three formations. Their combined thickness locally totals as much as 280 feet (sec. H-H'). The Degonia sandstone contains shale as well as sandstone.

The Caseyville sandstone of Pennsylvanian age is the youngest formation exposed in the Commodore area. As shown on plate 6, it may be as much as 200 feet thick. The scarcity of outcrops that permit accurate dip measurements precludes a more definite statement about the thickness of this formation.

For the purpose of describing the evidence for the geologic interpretations as shown on plate 6, the area is divided into three parts: the footwall side of the Commodore fault, the area between the Commodore and Glendale faults, and the hanging-wall side of the Commodore fault system.

On the footwall side of the Commodore fault the rocks are mapped as St. Louis limestone. Outcrops are poor, as the St. Louis limestone weathers readily to a cherty red soil. A few pits have been sunk along the footwall side, and the dumps from these pits contain fragments of St. Louis limestone. As boulders of oölite that resemble the Ste. Genevieve limestone were found locally, the lower part of the Ste. Genevieve limestone may crop out locally along the footwall side of the Commodore fault. However, the St. Louis limestone also contains some oölites, hence the oölitic texture is not completely diagnostic of the Ste. Genevieve limestone. Conversely, the Ste. Genevieve limestone may contain some chert, which generally is typical of the St. Louis limestone.

In December 1947 the Ozark-Mahoning Co. started a diamond-drilling program on the north end of the Commodore property. The writer examined the core from 4 drill holes, 3 from the footwall and 1 from the hanging wall of the fault. The footwall holes, drilled in the vicinity of the New No. 1 Commodore shaft, undoubtedly started in St. Louis limestone, which is a dark-gray fine- to medium-grained limestone with intercalated beds of dark-gray shaly limestone. Beds
of dark-gray oölitic limestone, however, were cut about 200 feet below the surface; these beds may be assigned to the Spergen limestone.

It is difficult to identify the formations between the Commodore and Glendale faults because of the scarcity of outcrops. Where major faults are close together as here, the intervening rocks are complexly fractured. The geology can be interpreted accurately only after many underground workings or cores of drill holes have been studied.

Sandstone crops out in most of the central block south of the Yandell shaft; its identification as Cypress or Bethel sandstone is based upon the information obtained from cores of diamond drill holes 3, 4, 5, and 6 and from study of the underground workings at the K. K. shafts. Typical Golconda limestone is exposed in a prospect pit about 100 feet northwest of diamond-drill hole 3. In that part of the central block north of the Yandell shaft, the identification of the Golconda limestone and Hardinsburg sandstone is based upon data from diamond-drill holes 7 and 8, and upon unpublished underground maps by A. H. Reed, Sr., of the Rock shaft of the Hickory Cane property. From the distribution of the outcrops, the contact of the Golconda limestone and Hardinsburg sandstone is from 500 to 600 feet north of the drill site for diamond-drill hole 6. Farther north the rocks excavated from three shafts that were caved in 1945 suggest that the Golconda was cut.

The Caseyville sandstone and the sequence of Kinkaid limestone, Degonia sandstone, and Clore limestone crop out on the hanging wall of the Commodore fault. In the area south of fault 54 the contact between the Caseyville sandstone and the Kinkaid limestone cannot be located on the surface. The Riggs shaft starts in Caseyville sandstone and crosses the contact with the Kinkaid limestone at a depth of 40 feet. The contact strikes northeasterly and dips 35° SE. From the Riggs shaft northeast to near diamond-drill holes 5 and 6, the trace of the contact at the surface is mapped on the basis of the strike and dip of the contact in the Riggs shaft. The dips of the strata along the fault system are known to change, however, and therefore this trend cannot be extended accurately for any great distance. The Kinkaid limestone is adjacent to the Glendale fault in the vicinity of diamond-drill hole 3. The nearest outcrop of Caseyville sandstone is at the dirt road, 250 feet east of the Glendale fault, and in other places as far east as Caney Fork. A narrow strip of Kinkaid limestone is inferred just northeast of diamond-drill hole 6 (pl. 6), although the limestone does not crop out. A few feet west of the Rock shaft, a steep sandstone cliff, 6–10 feet high, which ends abruptly against overburden on the west, is believed to be the eastern boundary of the strip of Kinkaid limestone. Since the surface trace of the Glendale fault is probably farther west, the area between the projected trace of the
fault and the sandstone cliff is thought to be weathered Kinkaid limestone.

North of fault 54 the contact of the Caseyville sandstone and Kinkaid limestone is offset to the east. This contact is exposed along an abandoned road (pl. 6., coordinates 38,000 N., 21,000 E.). Caseyville sandstone crops out also in the road near the top of the hill, about 300 feet east of the New No. 2 Commodore shaft. The lack of exposed bedrock below the hilltop suggests that weathered Kinkaid limestone may underlie this remnant of Caseyville sandstone. The nearly identical altitudes of these two places on or near the contacts of the two formations indicate that the strata are approximately horizontal. No direct measurement of the dip of the strata could be obtained.

The Ozark-Mahoning Co. in December 1947 drilled a hole in the hanging wall under the New No. 2 Commodore shaft, and penetrated shale, limestone, and sandstone of the Kinkaid, Degonia, Clore, and Palestine formations.

It is difficult to completely correlate the geology as mapped by the writer with that mapped by Ulrich (1905, pl. 8). Ulrich’s map shows 2 faults that diverge northeastward from the old LaRue mine, the east branch passing near the Glendale School. The eastern fault, called the Glendale by Ulrich, is identical with the Commodore fault system. The west branch, called the LaRue fault by Ulrich, lies west of the area mapped by the writer. Ulrich shows the Mansfield (Caseyville) sandstone on the hanging wall and his Birdsville formation (upper Chester) on the footwall of the Glendale fault, and St. Louis limestone on the footwall of his LaRue fault. Weller and the writer, however, found St. Louis limestone on the footwall of the Commodore (Ulrich’s Glendale) fault system.

**IGNEOUS ROCKS**

Although not exposed at the surface, dark colored igneous rock is known to be present in the northern part of the area. Ulrich and Smith (1905, p. 103) report that a sill was cut in a prospect shaft near Glendale Church (school). Weller (1927, p. 88–89) noted a dike of peridotite at Glendale (school). An unpublished mine map of the area near the Rock shaft shows several peridotite dikes and sills. Currier (1923, p. 21–33) noted that lamprophyre dikes and sills are common in the fluorspar district but does not describe any in the central Commodore area.

No surface exposures of igneous rocks were seen by the writer. The location of the dike, shown on the map about 100 feet east of the Rock shaft (pl. 6.), is based on the log of diamond-drill hole 7. Specimens of dark igneous rocks were found on the dumps near the Rock
shaft and also the New No. 2 Commodore shaft. The Ozark-Mahoning Co. drilled a hole in December 1947 under the New No. 2 Commodore shaft and cut about 8 feet of lamprophyre at a vertical depth of 150 feet. The lamprophyre is dark-gray with a medium-grained sugary texture. Irregular plates and small books of brown mica are abundant. A thin section of the lamprophyre shows that it is highly altered. The texture is holocrystalline with scattered, large metamorphs of calcite in a medium-grained groundmass that consists dominantly of calcite, biotite ($N\beta$ and $N\gamma$ between 1.61 and 1.62), and chlorite. Leucoxene, pyrite, magnetite(?), and ilmenite(?) are common. Apatite in rods and prismatic crystals is an accessory mineral. Anhedral crystals of plagioclase feldspar and quartz are sparse.

**STRUCTURE**

The central part of the Commodore area is broken by several high-angle faults that presumably are normal. The strata are generally flat lying, although along the hanging wall of the Commodore fault system south of fault 54, they dip as much as $40^\circ$ SE. The strata between the Commodore and Glendale faults also vary in dip. Cross-bedding locally is common in the sandstones, and where the outcrop is small the crossbedding may be misinterpreted as the true bedding.

The outstanding structure in the mapped area is the Commodore fault system which includes the Commodore and Glendale faults. Other known faults are Weller's fault 54 (1927, p. 104, 113) and a fault associated with a dike near the Rock shaft. Additional faults undoubtedly occur in the mapped area, particularly between the Commodore and Glendale faults.

**COMMODORE FAULT SYSTEM**

The Commodore fault system strikes northeast and dips steeply southeast. The total displacement is between 1,500 and 2,000 feet, the northwest side being upthrown. Except for the extreme north and south parts, the fault system is divisible into two subparallel major faults, the Commodore fault on the northwest side, and the Glendale fault on the southeast side. Where the two faults are close together, the included fault block is commonly so broken and fractured that it is not possible to distinguish the intervening formations.

The St. Louis limestone is at the surface northwest of the fault system; the Kinkaid limestone is on the southeast side. The Cypress sandstone, Paint Creek shale, and Bethel sandstone sequence, Golconda limestone, and the Hardinsburg sandstone crop out within the fault block.

The Glendale fault probably branches from the Commodore fault near the north edge of the Lafayette property, and can be traced at
least as far north as the vicinity of the Rock shaft. On the Commodore property, the best evidence for the continuation of the Glendale fault was found in diamond-drill hole 8. Nearly 400 feet of limestone and shale with a few very thin sandstone layers were cut. As the hole probably started in the Kinkaid limestone, such a thick sequence of limestone and shale is not to be expected in a typical section here. Calcite veins at a depth of 250 feet in the drill hole suggest a fault, presumably the Glendale fault. Mineralized rock, considered to be evidence of the Commodore fault, was cut near the bottom of the drill hole. Farther north the Glendale fault probably joins the Commodore fault.

OTHER FAULTS

In his regional study, Weller (1927, p. 104, 113) mapped fault 54 as passing just north of Glendale School. At this locality, the writer found the following evidences for the fault: the offset of the contact of the Caseyville sandstone and the Kinkaid limestone, and a few slickensided sandstone boulders on the hillslope north of Glendale School. The strata are downthrown 25-50 feet on the south side of fault 54.

A fault along a dike of lamprophyre is believed to be present on the Hickory Cane property near the Rock shaft. Such a fault has been inferred from the stratigraphy as given in a generalized log of diamond-drill hole 7. The fault strikes N. 20° W., presumably similar in direction to that of several dikes in the vicinity, as shown on an unpublished mine map of the Rock shaft. The displacement is probably less than 40 feet (pl. 6, cross section G-G').

FLUORSPAR DEPOSITS

The fluorspar and zinc mines along the central part of the Commodore fault system, Crittenden County, Ky., have been worked intermittently since 1892. Approximately 30,000-40,000 tons of fluorspar, 20,000 tons of zinc ore, and a small tonnage of lead ore have been produced.

GENERAL FEATURES

Fluorite, calcite, sphalerite, smithsonite, and galena are the most abundant minerals in the area. Small quantities of pyrite and quartz are present. The fluorite is purple and fine- to medium-grained in veinlets, but is brown massive and coarse-grained in veins and gravel spar. The calcite is white to medium brown, generally coarse-grained, and commonly occurs as veinlets in the limestone and as large massive veins. Quartz locally lines vugs and forms veinlets of fine-grained material. The silica content of the fluorspar veins is generally low,
and most of the silica that is mined with the fluorspar is from the sandstone country rock.

Sphalerite typically occurs as red to brown fine disseminated grains in the limestone, fluorite, and calcite. In a few places the disseminated sphalerite becomes so concentrated that it appears to be massive. Smithsonite, the principal zinc mineral of the central Commodore area, generally is in gray irregular-shaped porous masses associated with partly weathered limestone. Presumably it formed by the alteration of sphalerite. Fine-grained disseminated galena is associated with the sphalerite and fluorite in places, and also with the fluorite alone. Small disseminated crystals and very small veinlets of pyrite were noted locally in the vein material and in the adjacent sandstones.

Most of the minable fluorspar deposits in the area are of the gravel-spar type, concentrated by the weathering of country rock and veins. With the possible exception of part of the fluorspar body at the Commodore mine, none of the veins in unweathered bedrock have been of minable size. The gravel-spar deposits consist of coarse-grained, generally brown fragments of fluorite in a matrix of clay, mud, and a few remnants of limestone and vein calcite. In places narrow veins of fluorite have been preserved in the zone of gravel spar.

Within the area studied, the mineral deposits are localized along the Commodore fault system, and no deposits are known along the other faults.

Four main fluorspar or zinc deposits have been mined in the central Commodore area: the K. K. fluorspar body near the K. K. No. 1 shaft, the K. K. zinc and fluorspar body near the K. K. No. 3 shaft, the Hickory Cane zinc body near the Rock shaft, and the Commodore zinc and fluorspar body near the Old Main Commodore shaft.

Data on the size and grade of these ore deposits were obtained mostly from unpublished maps and reports of A. H. Reed, Sr. The dimensions of the stopes (pl. 5) were used to approximate the size of the ore bodies, as no other information was available.

The K. K. fluorspar body, mined from the No. 1 shaft, was about 85 feet long, 75 feet deep, and from less than an inch to 12 feet wide. It is reported to have averaged 75 percent calcium fluoride and 10 percent silica.

The K. K. zinc and fluorspar body, mined from the No. 3 shaft, is reported to have been 180 feet long, 40 feet deep, and 4-5 feet wide. No data on the grade of the ore are available.

The Hickory Cane zinc body was approximately 400 feet long and more than 100 feet deep. Estimates of the average widths and grades of the ore, which was mostly carbonate, are not available.

The Commodore ore body was chiefly fluorspar from the surface to a depth of 125 feet and zinc ore from 125 to 200 feet. It was approxi-
mately 175 feet long. The zinc ore is reported to have been 8–10 feet wide, but the width of the fluorspar is unknown to the writer.

The wall rocks of the known ore bodies of fluorspar and zinc are as follows: The K. K. fluorspar body, on the Glendale fault, lies between a footwall of Cypress or Bethel sandstone and a hanging-wall sequence of Kinkaid limestone, Degonia sandstone, and Clore limestone. The K. K. zinc and fluorspar body, on the Commodore fault, is between the Bethel (?) sandstone and the St. Louis limestone. The wall rocks of the Hickory Cane zinc body near the Rock shaft probably are the Kinkaid, Degonia, Clore, Golconda (†), Cypress, Bethel, and St. Louis formations. The Commodore fluorspar body is probably between the St. Louis limestone on the footwall and the Cypress sandstone and possibly the Golconda limestone on the hanging wall.

McFarlan (1943, p. 391–395) briefly summarizes various theories that have been proposed for the origin of the fluorspar deposits of western Kentucky. The deposits generally are considered to be hydrothermal, the ore-bearing solutions presumably originating from some underlying large intrusive mass of igneous rock, as yet not found. Weller and Grogan (1945, p. 398–402) have found fragments of weathered granite in Pope County, Ill. It is not known whether the granite fragments were derived from some now unexposed intrusive body or whether they are of glacial origin.

No conclusions about the primary origin of the fluorspar bodies can be drawn from studies along the central part of the Commodore fault system, because the underground workings seen at the Pasco and K. K. No. 2 shafts, and probably those of most of the other deposits, are in deposits of gravel spar.

**DESCRIPTIONS OF MINES AND PROSPECTS**

**BEBOUT**

Only the north end of the Bebout property (pls. 5 and 6) is included in the mapped area. There are two shafts on the property, the Bebout and the Riggs. The Bebout shaft is caved and inaccessible, but is reported to be 50 feet deep; at a depth of 40 feet in the shaft, a short crosscut was driven northwestward to the Commodore fault to a fluorspar and galena vein. In 1944, a lessee sank the Riggs shaft to a depth of at least 90 feet, but no vein was found to that depth. The shaft first passed through about 40 feet of Caseyville sandstone and then 50 feet of Kinkaid limestone. The beds strike approximately S. 30° W., and dips 35°–40° SE.

**LAFAYETTE**

Only the northern part of the Lafayette property (pls. 5 and 6) was mapped. Two shafts have been sunk, the Reed shaft and the Lead shaft; both were inaccessible in 1945.
The Reed shaft was sunk about 50 feet, entirely in overburden derived from weathered St. Louis limestone. A crosscut was driven in the overburden for a distance of about 265 feet southeast to a lead vein, which is probably along the Commodore fault. From the intersection of the crosscut with the lead vein, a raise to the surface and a winze were excavated for a combined total depth of 100 feet. This combined raise and winze is known as the Lead shaft. A drift is reported to have been driven from the bottom of the shaft, following the lead vein. The dump near the Lead shaft contains pieces of galena a few inches in diameter and some pieces of limestone with small grains of disseminated galena.

PASCO

The Pasco property (pls. 5 and 6) was first prospected during World War I. A small tonnage of fluorspar probably was shipped during the prospecting operations. The mine openings on the property are the Pasco shaft, said to be 100 feet deep, and several shallow prospect shafts and pits. Lessees worked the 66-foot level of the Pasco shaft for a short period during the fall of 1943. A brief study of this level was made by the writer, but poor ventilation prevented a more detailed examination. The Pasco shaft starts in the hanging wall of the Commodore fault and cuts the fault at a depth of about 60 feet. The fracture zone contains gravel spar, which consists of clay, gouge, and fragments of fluorite. A short crosscut on the 66-foot level also cuts the Commodore fault. Drifts extend southwest and northeast of the shaft at the 66-foot level. Only about 40 feet of the southwest drift was accessible in 1943. A long crosscut from the bottom of the shaft is reported to cut both the Commodore and Glendale faults, but no mining was done.

K. K.

The first mention in literature of the K. K. property (pls. 5 and 6) is by Currier (1923, p. 106) who discussed the mining operations in 1920. Fluorspar was produced from this property during the period 1916-1919 and also during the middle 1930's. From 25,000 to 35,000 tons of fluorspar, containing an average of 75 percent of calcium fluoride and 10 percent of silica, and about 2,000 tons of zinc carbonate were mined during these times. Most of the fluorspar came from the southern part of the property, and the zinc ore came from the northern part. Lessees mined about 800 tons of fluorspar from the No. 2 shaft from 1940 through 1943.

The No. 2 shaft, which cuts the Glendale fault, was the only one on the property that was accessible to the writer (fig. 3 and pls. 5 and 6, cross section A-A'). It is 130 feet deep, with crosscuts and drifts at depths of 100 and 130 feet. An 18-foot winze was sunk on the vein from the 100-foot level, and a short drift was driven southwestward at
the bottom. The fluorspar zone consisted chiefly of gravel spar, red clay, and gouge, with a few veins of coarse-grained brown fluorite. The zone containing fluorspar ranged in width from 2 to 8 feet. In 1944 an exploratory crosscut from the 130-foot level was driven westward in Bethel(?) sandstone, and is reported to have cut the Commodore fault. No minable deposits were found.

Most of the fluorspar production from the property was from the No. 1 shaft (pls. 5 and 6), which is 185 feet deep, with crosscuts and drifts at depths of 110, 150, and 185 feet. Bodies of gravel spar were cut on all three levels and ranged in width from less than an inch to 12 feet, 4 feet being average. Mining was abandoned at the shaft because of caving.

Shafts Nos. 3 and 4 are 150 and 90 feet deep, respectively, with levels at the bottom of each; they are connected on the 90-foot level (pl. 5). Zinc carbonate (smithsonite) was the most abundant vein material found, and was reported to be as much as 4 or 5 feet wide in the No. 3 shaft. The Dover shaft (pl. 6) was sunk in 1941 or early 1942, to a depth of 24 feet in Cypress(?) sandstone. There are many other shallow caved shafts and pits on the K. K. property, but no information concerning them is available.
Four diamond-drill holes have been put down on the K. K. property, three of them in 1929 and a fourth by the U. S. Bureau of Mines in 1945. Diamond-drill hole 1 (pl. 6, cross section C-C'), 930 feet deep, was started in St. Louis limestone and remained in limestone to the bottom. The hole was drilled southeastward from the footwall side of the Commodore fault at an angle of 67°. A study of the core indicates that the hole did not cut the southeastward-dipping Commodore fault, but apparently was parallel with it.

Diamond-drill hole 2, cross section C-C', 880 feet deep, was drilled from the same location and in the same direction as diamond-drill hole 1 but at an angle of 52½°. This hole cut scattered veinlets of fluorspar, zinc minerals, and lead minerals from a depth of 400 feet to the bottom. The great length of core containing small quantities of ore minerals suggests that the drill hole intersected the fault zone at a small angle.

Diamond-drill hole 3, cross section B-B', was started from the hanging wall of the Glendale fault at an angle of 45°. Based on a generalized log of this hole the writer believes that the hole cut Kinkaid limestone for 80 feet, crossed the Glendale fault at a barren section, and continued to the bottom, 138 feet, in Bethel (?) sandstone.

Diamond-drill hole 4 (Starnes and Hickman, 1946, p. 44), shown in cross section D-D', was drilled northwestward from the hanging wall of the Glendale fault to a depth of 272 feet at an angle of 50°. No commercial fluorspar or zinc ore bodies were found.

SULLENGER

Although Currier (1923, p. 107) briefly mentioned the Sullenger property, no other historical data are available. The east boundary of the Sullenger property with the Hickory Cane property was in dispute in 1945. Two shafts, the Null shaft and the Maddox shaft, were sunk in 1941, 1944, and 1945 by lessees, who obtained leases from the owners of the Sullenger property. The maps (pls. 5 and 6) accompanying this report suggest that these shafts are on the Hickory Cane property and they are therefore described below under the section on that property. It should be emphasized, however, that the property lines could not be located accurately because of the vagueness of the descriptions of the original property surveys and the lack of property-line markers. Therefore the maps should not be taken as evidence for the relative position of the shafts and property lines.

Mine openings that are definitely on the Sullenger property (pl. 6) consist of several caved, shallow prospect pits. A small tonnage of gravel spar was mined. The mine waste left on the surface is mostly weathered limestone with abundant chert, calcite, veinlets of fluorite, and a few small grains of sphalerite and galena.
HICKORY CANE

Mining probably started about 1901 on the Hickory Cane property (pls. 5 and 6), and both fluorspar and zinc ore have been produced. Most of the 7,000–8,000 tons of zinc carbonate was mined from the northern part of the property in 1924 and 1925. Workings on the property consist of several shafts and prospect pits, the deepest being the Rock shaft, 240 feet. The mine workings in the northern part of the property are the oldest and most numerous. Recently various mine operators have worked in the southern part of the property. During 1941, 1942, 1944, and 1945, small quantities of fluorspar were mined from the Yandell shaft, the Null shaft, and the Maddox shaft.

The Rock shaft has levels at depths of 25, 60, 120, 155, 160, 200, and 240 feet. Considerable stoping was done, particularly between the 60- and 160-foot levels. According to Reed, smithsonite, sphalerite, and galena are present in the workings of the Rock shaft and the smithsonite extends to a depth of 160 feet. From 160 feet to 240 feet and adjacent to the footwall of the Glendale fault, galena is reported to occur in a zone 4–5 feet wide. Toward the hanging wall, brecciated calcite, 12–15 feet wide, is reported to contain disseminated sphalerite and galena. This brecciated zone is said to contain 25–30 percent of sphalerite and 3–4 percent of galena. It is reported that on the 240-foot level the ore contained up to 15 percent of sphalerite and as much as 1 percent of galena.

There are many other shafts, all inaccessible, west of the Rock shaft. Some of these old shafts may be as much as 155 feet deep. The most abundant vein mineral on the shaft dumps is smithsonite. Some sphalerite with subordinate galena and fluorite also is present.

From November 1941 to March 1942, about 215 tons of gravel spar was produced from the 35-foot level of the Maddox shaft. Later, the shaft was sunk to a depth of 60 feet and a crosscut was made to the vein (fig. 4). A vertical raise was cut to the surface in 1945 and called the Yandell shaft (Starnes and Hickman, 1946, p. 43). The drift on the 60-foot level is along the Commodore fault, with Bethel (?) sandstone on the hanging wall and St. Louis limestone on the footwall. The fault zone contains mud, gouge, calcite, fragments and veins of fluor spar, and disseminated sphalerite and galena. Fluorite is the most abundant of the vein minerals.

The Null shaft was sunk in 1944 to a depth of 55 feet. Dispute as to the location of the Sullenger-Hickory Cane property line stopped operations.

Three diamond-drill holes (pl. 6) were completed on the Hickory Cane property. About 1929, diamond-drill hole 7 was put down 335 feet at an angle of 60°. The writer’s stratigraphic interpretation of a
generalized log of this hole is shown in plate 6, cross section $G-G'$. The fault zone of the Commodore fault system contained calcite with disseminated sphalerite and galena, and included an 18-inch vein of massive sphalerite. The other two drill holes were put down by the U. S. Bureau of Mines in 1945 (Starnes and Hickman, 1946, p. 43) in the southern part of the property. The first of them, diamond-drill hole 5 (cross section $E-E'$), is 300 feet long, and was drilled northwestward at an angle of 50°; the second hole, diamond-drill hole 6 (cross-section $F-F'$), is 360 feet long and was drilled also northward at an angle of 50°. No minable fluorspar or zinc ore bodies were indicated by diamond-drill holes 5 and 6.

**COMMODORE**

Mining in the central Commodore area started on the Commodore property (pl. 6) in 1892. The Original Shaft is reported to be the first shaft sunk. The first major mining operation was undertaken during the period 1905–1909, and about 10,000 tons of zinc ore was mined from the Old Main Shaft. Formerly a mill on the property concentrated the ore. During World War I, a large quantity of fluorspar was mined from the upper levels of the Old Main shaft. Exploration
work was done on the property in 1942, when lessees sank the New No. 1 and New No. 2 shafts to depths of 100 and 114 feet, respectively, and drove short drifts from the bottoms of these shafts.

None of the workings were accessible when the area was mapped by the writer. Currier (1923, p. 106-107) describes the Old Main shaft and workings, and states that the shaft is 300 feet deep. According to an unpublished mine map made by A. H. Reed, Sr., the Old Main shaft is 240 feet deep, with levels at depths of 100 and 200 feet. The dump material in the area near the Old Main shaft is composed chiefly of limestone with large quantities of light-brown and white coarse grained calcite. Pieces of purple and brown fluorite with disseminated sphalerite and galena are common.

In the New No. 1 shaft, a former lessee reports 2½–4 feet of fluor spar and sphalerite. The vein in the drift assayed 35–66 percent of calcium fluoride, 6–10 percent of zinc, 3–27 percent of calcium carbonate, 14–31 percent of silica, and traces of lead. In the New No. 2 shaft, a former lessee reports that 8 feet of calcite and fluorite with traces of sphalerite are present.

Two diamond-drill holes have been put down on the Commodore property. One hole, whose location is unknown, is said to have cut the workings near the Old Main shaft. The other, diamond-drill hole 8 (pl. 6, cross section H–H') was drilled northwestward for 436 feet at an angle of 60°. Several small veinlets of fluorite were reported to have been cut.

**Jenkins**

A small quantity of fluor spar has been produced from the Jenkins property. Two shafts, the Perryman and the Jenkins, and a few prospect pits have been sunk on the property. Neither shaft is accessible, but according to local reports, the Perryman shaft is 97 feet deep and the Jenkins shaft is 50 feet deep. A fluor spar vein 2–4 feet thick is reported to have been found in the bottom of each shaft. Waste piles near the shafts consist chiefly of limestone breccia and calcite with a few veinlets of purple fluorite and a trace of sphalerite.

Three diamond-drill holes (pl. 6, cross section I–I') were put down by a lessee in 1943. Diamond-drill holes 9 and 10 were drilled northwestward at angles of 45° and 60° and for lengths of 149 and 147 feet, respectively. Diamond-drill hole 11 was started at an angle of 60° but was abandoned because of poor core recovery. Although the Commodore fault system was definitely cut in diamond-drill hole 9 and possibly 10, no core was obtained that indicated deposits of minable fluor spar or zinc ore.
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ABSTRACT

The Mineral Ridge area, in the south southwestern part of the Kentucky-Illinois fluorspar field, is broken by a complex northeastward-trending system of steeply dipping normal faults. Mining activity started in the Mineral Ridge area in about 1870. More than 25,000 tons of fluorspar and small quantities of zinc and lead have been produced, most coming from the Mineral Ridge No. 1 property, in the northeastern part of the mapped area. The other properties have produced only small quantities of ore.

The ore deposits are localized along faults that displace relatively flat-lying shales, sandstones, and limestones of the Chester and Meramec groups of Carboniferous age. Stratigraphic displacements range from a few feet to about 700 feet. Detailed geologic mapping of the surface and data from underground workings and diamond drilling have revealed 34 faults. Only a few of these faults contain economic deposits of fluorspar.

The most abundant vein minerals are calcite and fluorite, with subordinate quantities of sphalerite, galena, smithsonite, quartz, marcasite, and pyrite. Fluorspar bodies are of two types—gravel-spar deposits and vein deposits. The gravel-spar deposits are generally composed of high-grade fluorspar; the vein deposits are composed of calcite and fluorite. The sphalerite and galena generally are associated with the fluorite.

The localization of the vein deposits within the faults is believed to have depended primarily upon the availability of space for deposition. Replacement of the wall rock or vein minerals by mineralizing solutions has been slight.

INTRODUCTION

The Mineral Ridge fluorspar area is about 3½ miles southeast of Salem, Ky., in the eastern part of Livingston County and the southwestern part of Crittenden County (fig. 5). The area can be reached from Salem by going about 4 miles southeast on a graded gravel road that branches from U. S. Highway 60 at the eastern edge of Salem. The nearest railway terminal is at Marion, about 14 miles northeast of the area.
More than 25,000 tons of fluorspar and small quantities of zinc and lead have been mined in the area since about 1870. Most of the fluorspar, lead, and zinc came from the Mineral Ridge No. 1 property; other productive mines include the Riley, the Goering, the Billy Owl, and the Green Mines.

The area mapped and studied is rectangular, about 12,000 feet by 1,350 feet, and elongate to the northeast. Locally, the name Mineral Ridge refers to the northeastern part of the Mineral Ridge No. 1 property, but in this report the name Mineral Ridge is applied to the entire mapped area. Mining has been done at various places along both sides of a narrow wooded northeast-trending ridge. Altitudes range from 330 feet to 490 feet above mean sea level.

The first mention of mining in the Mineral Ridge area was by Norwood (1876, p. 465-469) who described pits belonging to Tisdal, Henry Woods, and Robert Woods. From Norwood’s map and descrip-
tion, these three shafts are probably on the Goering (formerly Woods) property.

Ulrich and Smith (1905, p. 195, 196) mention the Henry Woods and Hodge prospects, and the Riley mine. The Hodge prospect also is probably on the Goering property.

Fohs (1907) referred briefly to the Riley (p. 38, 222), Martin (p. 228), Woods (p. 230), and Tisdale (p. 230) prospects. Hoeing (1913) mentioned the Goering (Woods) and the Wallace (Pierce) properties. Currier (1923, p. 127, 128) described briefly a few prospects in the northeastern part of the mapped area. Sutton (Weller and Sutton, 1940; 1951) in 1929 mapped the geology of the Eddyville quadrangle, which includes the Mineral Ridge area.

In August of 1942 the U. S. Bureau of Mines examined the Mineral Ridge No. 1 property and in 1945 explored parts of the Woods fault and adjacent fractures by diamond drilling (Muir, 1947).

As part of the U. S. Geological Survey's program for the investigation of strategic and critical minerals, field study of the Mineral Ridge area was started in November 1942 and continued intermittently until March 1948. Field work was under the general supervision of James Steele Williams and R. E. Van Alstine. The geology of the area south of the road from Salem to Dycusburg was mapped mostly by R. T. Russell, with modifications and additions by the writer. Several other members of the U. S. Geological Survey, including H. J. Klepser, G. C. Hardin, Jr., W. R. Thurston, and D. A. Warner, have collaborated with Russell and the writer. The final responsibility for the work, however, is the writer's.

A. H. Reed, Sr., mining engineer of Marion, Ky., contributed data on inaccessible workings and historical information. The Ozark-Mahoning Co. furnished mine maps of the 215- and 300-foot levels of the John Pace shaft, drill-hole locations and logs of the Riley and Goering drill holes, and several property maps. The writer is particularly indebted to E. A. Brecke, engineer and geologist of the Ozark-Mahoning Co., for information about the area.

A system of coordinates was established in order to facilitate location of points in the Kentucky fluor spar district. The U. S. Geological Survey bench mark set in the concrete sidewalk about 40 feet west of the southwest corner of Grassham's garage at the corner of North Hayden and West Broadway Streets in Salem, Ky., was chosen as the zero point, and coordinate lines were extended from this point. (See coordinates on pl. 7.)

GEOL OGY

GENERAL FEATURES

The surface geology of the area northeast of the Salem-Dycusburg road is better known than that of the area to the southwest (pl. 7).
The northeastern part of the area has many drill holes and accessible mine workings. In contrast, the southwestern area has one diamond-drill hole and few accessible underground workings. Drill-hole data show that parts of the Mineral Ridge area are complexly faulted, and many structural interpretations are possible because of the difficulty in identifying the relatively small slivers of the formations in the faulted area.

The bed rocks exposed in the area are sandstone, limestone, and shale of the Meramec and Chester groups of Carboniferous age. No igneous rocks are exposed or have been reported. The sedimentary rocks are approximately horizontal except near faults, where beds have been dragged to various angles by movement along the fault planes. The complexly faulted area is bounded by two northeast-trending normal faults, the Clay Lick fault on the northwest, and the Woods fault on the southeast. The intervening faults have been given numbers arbitrarily by the writer for purposes of description (pl. 7). The stratigraphic displacement along the faults ranges from a few feet to at least 700 feet.

The relationship of topography to lithology and structure is clearly shown in the Mineral Ridge area. The northeast-trending ridge is a fault block of sandstone of the Chester group flanked by limestones of the Meramec group. Within the complexly faulted area the relationship is shown on a smaller scale by several "quartzite reefs," a local term for small ridges of silicified sandstone commonly present along faults in the area.

The thickness of overburden in the area generally varies with the type of underlying bedrock. Ordinarily the overburden above limestone averages about 20 feet in thickness, but may be as much as 70 feet. The overburden above sandstone, however, is very thin, usually ranging from 2 to 5 feet thick.

**SEDIMENTARY ROCKS**

The recognition of the formations in this complexly faulted area is a very difficult task. Because of few surface outcrops, most of the stratigraphic information is based upon drill-hole information. A drill may penetrate only a small part or sliver of a formation between faults. As a result, unless the lithology is particularly distinctive, the formation cannot be identified positively. Fossils were of little value in distinguishing formations, as most of the data came from drill holes. *Platycrinus penicillus* specimens confirmed the identification of the Ste. Genevieve limestone, and some species of *Lithostrotion* confirmed the identification of a few outcrops of St. Louis limestone. The formations exposed in the mapped area and their character and thickness are summarized in figure 6.
<table>
<thead>
<tr>
<th>Age</th>
<th>Formation and member</th>
<th>Thickness (feet)</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Alluvium</td>
<td>0 - 40</td>
<td>Silt, sand, and gravel; unconsolidated</td>
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<tr>
<td></td>
<td>Glen Dean limestone</td>
<td>25 +</td>
<td>Limestone, medium-gray, medium-grained; lower part of formation</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Sandstone, light-gray, fine-grained, with a few thin fissile gray shale beds</td>
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<tr>
<td></td>
<td>Hardinsburg sandstone</td>
<td>125 ±</td>
<td>Limestone, light- to dark-gray, fine- to medium-grained, with interbedded calcareous medium-gray shale. Upper shale beds are 0.5 to 1 foot thick and as much as 12 feet thick in lower part of formation</td>
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<td></td>
<td></td>
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<td>Sandstone, light-gray, fine-grained, with a few thin shale beds</td>
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<td>Limestone, medium- to dark-gray, fine- to medium-grained, commonly with shaly partings; 6- to 8-foot shale bed near top</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Shale, black and gray, commonly massive; or thin beds of intercalated shale and sandstone</td>
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<td></td>
<td></td>
<td></td>
<td>Sandstone, light-gray, fine-grained, with a few thin shale beds</td>
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<td>Limestone, medium- to dark-gray, fine- to medium-grained, commonly with shaly partings; green and black shale beds 1 - 10 feet thick; locally medium-gray fine-grained oolitic limestone beds about 2 feet thick; 5- to 10-foot bed of shale commonly at upper contact; locally 2-foot calcareous sandstone bed is present in the middle and near the top of the formation</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Limestone, light- to medium-gray, generally oolitic</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Limestone, light-gray, fine-grained, sandy, or light greenish-gray sandstone</td>
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<td></td>
<td></td>
<td></td>
<td>Limestone, light- to medium-gray, fine- to coarse-grained, generally oolitic; in places contains shaly limestone beds and thin beds of green shale</td>
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<tr>
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<td></td>
<td>Limestone, medium-gray, fine-grained, commonly with irregular-shaped dark-blue chert nodules 1 - 2 inches thick; locally is oolitic; may contain shaly partings; bottom not exposed</td>
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<tr>
<td>Carboniferous</td>
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Figure 6.—Section of formations exposed in the Mineral Ridge area, Livingston and Crittenden Counties, Ky.
The St. Louis limestone of the Meramec group is the oldest exposed formation. Most of the area southeast of the Woods fault is underlain by St. Louis limestone. This area (pl. 7), however, is labelled undifferentiated St. Louis and Ste. Genevieve limestone, as some Ste. Genevieve limestone is known to be present on the footwall of the Woods fault in the vicinity of the John Pace shaft and also in places to the southwest. Residual chert of the St. Louis limestone also is found at the same and even higher altitudes. Faulting and associated drag folding probably occurred in the limestone footwall of the Woods fault, but because of the depth of overburden and lack of drill holes and mine workings, the faults could not be found.

The Ste. Genevieve limestone, also of the Meramec group, is present along the footwall of the Clay Lick fault, and also locally within the complexly faulted area. The formation is distinguished mainly on lithology. The bottom of the formation is placed at the lowermost bed of coarse-grained white oolitic limestone. The upper contact with the overlying Renault formation of the Chester group is drawn where the limestone becomes argillaceous. Commonly a shale bed is present in the lowermost part of the Renault. Some oolitic limestone may occur near the base of the Renault formation, but it is uncommon, and if present, the texture is noticeably finer grained than that of the Ste. Genevieve limestone. In some of the drill cores the Ste. Genevieve limestone has been differentiated into the Fredonia limestone, Rosiclare sandstone, and Levias limestone members (pl. 7).

The Chester group consists of alternating beds of limestone, sandstone, and shale. The sandstone formations are similar in many respects and it is difficult to differentiate among them unless an overlying or underlying formation is exposed also.

The Renault formation is composed of limestone and shale, typical of the formation elsewhere in the fluorspar field. Disseminated pyrite was noted locally. Individual grains or cubic crystals of pyrite average 0.1 millimeter in diameter but are as large as 0.8 millimeter; a few clusters of grains may be as large as 4 millimeters in diameter. A shale bed as much as 10 feet thick occurs locally in the uppermost part of the formation.

The Bethel, Paint Creek, and Cypress formations are dominantly sandstone with subordinate shale. These three formations were not differentiated in mapping. The Paint Creek shale could not be identified in most of the drill holes and probably is absent in places. The upper contact of the Cypress sandstone with the overlying Golconda formation in most places is gradational. The gradational zone, composed of thin beds of sandstone and limestone, is about 5 feet thick. Sandy shale, 6–8 feet thick, also occurs commonly at the top of the Cypress sandstone.
The Golconda formation is characterized in the Mineral Ridge area by thin interbedded shale and argillaceous limestone beds. The contact of the Golconda with the overlying Hardinsburg sandstone generally is sharp.

The Hardinsburg sandstone does not crop out and only a part of what is believed to be Hardinsburg sandstone was penetrated by a drill. It is primarily a sandstone, with a few thin shale beds.

The overlying Glen Dean limestone, the youngest Chester formation found in the Mineral Ridge area, may be exposed in one small area on the southwestern part of the Mineral Ridge No. 1 property. Irregular to roughly spherical chert pebbles are found on the dump near a small pit on the Wallace property at coordinates 16,050 S. and 10,420 E. The pebbles are light gray, commonly brown stained and range in diameter from less than half an inch to 3 inches, averaging about half an inch. As this gravel was not found elsewhere in the Mineral Ridge area, and the area over which it crops out could not be traced, it is not mapped separately. Gravel similar to that on the Wallace property was reported to the writer by Sutton (oral communication) as the Tuscaloosa formation of Cretaceous age. Roberts described this formation in 1931.

Quaternary alluvial deposits of unconsolidated sand, silt, and gravel are found along Puckett Springs Branch (pl. 7).

STRUCTURE

The fault pattern of the mapped area (pl. 7) is complex, and surface information is inadequate to map the details. In the northeast part of the area, drilling and underground workings have furnished sufficient data for mapping a complex network of faults. South of the Salem-Dycusburg road, however, most of the fault pattern has been determined primarily from outcrops.

The best surface indications of faulting are fault breccia, evidences of mineralization, and the presence on the waste pile from shallow pits or shafts of rock belonging to stratigraphically widely separated formations. The relationship of topography to faulting has already been mentioned. In the Mineral Ridge area, this criterion, on a large as well as small scale, is of great value. Widely separated beds cropping out within a small area also indicate the presence of faults.

The rocks of the area are broken by two main normal high-angle faults, the Clay Lick fault (Weller’s No. 74) and the Woods fault (Weller’s No. 75). These faults are farthest apart (nearly 1,100 feet) in the central part of the area (pl. 7). The faults converge both to the northeast and southwest. Southwest of the Salem-Dycusburg road, the faults generally are about 500 feet apart, although at the extreme southwest end of the mapped area they are...
only about 100 feet apart. The two main faults range in dip from 70° toward each other to vertical. The downthrown grabenlike block between the bounding faults is broken by numerous normal faults; many fractures probably exist that are not shown on the map.

The amount of displacement along both the Clay Lick and Woods faults varies considerably. Between these bounding faults, cross faults have allowed some blocks to drop down more than others. The common displacement along the main faults is 300-400 feet, although a displacement of as much as 700 feet is known (pl. 7, section N-N'), bringing the Hardinsburg sandstone and Glen Dean limestone next to the St. Louis or Ste. Genevieve limestones. The displacement along cross faults is ordinarily less.

Dragged beds along most of the faults suggest that the movement was essentially vertical. Brecciation of beds is common along the faults. Most of the dislocation took place before mineralization, although the sheeted condition of the fluorspar veins probably suggests some postmineralization movement.

Where seen, the footwalls of the faults are not as brecciated as are the hanging walls. The footwall edges of the fault zones are commonly sharp and well defined, whereas the boundaries between the fault zone and the rock of the hanging wall are gradational and the hanging walls are cut by a series of en échelon faults. Seams of clayey fault gouge, generally a few inches wide, are abundant along the faults, particularly near the hanging wall. Commonly these seams of fault gouge are parallel to the fault and are interspersed between veins of fluorspar and calcite.

The age relationships of the faults could not be determined in detail. Mostly they are essentially contemporaneous, although some of the cross faults are probably a little younger than the northeast-trending main faults.

The fault pattern of the area has been mapped by Norwood (1876), Ulrich and Smith (1905), Weller (1926) and Sutton (Weller and Sutton, 1951). Norwood showed a single fault, the Excelsior, through the Mineral Ridge area. Ulrich first advanced the conception of two major faults, the "Marion" fault on the northwest and the Woods faults on the southeast, with intervening minor faults. Later work by Weller has shown that Ulrich's Marion fault is actually two different faults, and Weller has used the name Marion to describe a fault outside the mapped area. Therefore the name is discarded for the Mineral Ridge area and Weller's term "Clay Lick fault" is used here. The name "Woods fault" is retained for the southeast-bounding fault.

Previous mapping was done on scales of roughly 1 inch to 2 miles (Ulrich, 1905) and 1 inch to 1 mile (Weller and Sutton, 1951), on
which it was impracticable to show the detail shown herein. The overall structural pattern, however, is but slightly changed from the older work. The mapping scales used formerly forced the previous workers to show the two major faults essentially as straight lines. Large scale mapping has suggested that the faults are curved in places.

Many details of the 34 faults are omitted from the following discussion inasmuch as the information is presented graphically (pl. 7).

The Clay Lick fault is the fault farthest northwest in the mapped area. This fault generally cannot be located definitely and is mapped mostly from topographic evidence. The Martin mine (pl. 7) is the only working along this fault.

The Wood fault, on the other hand, has been traced by extensive workings and many diamond-drill cores. Most of the ore produced in the area has come from this fault.

Fault 1 is a hypothetical fault, whose presence is suggested by the juxtaposition of the Cypress and Golconda formations near the bottom of the hill slope, with a massive-bedded sandstone, believed to be Cypress, on top of the hill. No outcrop of the fault was noted.

Fault 2 is a long fault, subparallel with the Clay Lick and Woods faults, and probably formed contemporaneously with them. Fault 17 (pl. 7) may be a continuation of this fault, but offset by fault 15. Fault 2 was traced along most of its extent by surface workings and diamond drilling. It is probably the second most productive fault in the area.

As most of the faults are nearly vertical normal faults, fault 3 is unusual in two respects: first, underground workings from the John Pace shaft show that above the 215-foot level it dips about 63° NW. (section D-D'), and second, recurrent movement along it that accompanied nearby younger faulting was of the reverse type (section C-C').

Fault 4 is hypothetical, based on stratigraphic evidence shown in cores of diamond-drill holes (sections C-C' and D-D').

Fault 5 was located by underground diamond drilling from the 215-foot level of the John Pace shaft. The 300-foot level on the northeast end curves as though to follow fault 5, rather than the Woods fault (fig. 6).

Fault 6, cut by several diamond-drill holes, nearly parallels fault 2 throughout its length. Fault 16 may be part of fault 6 offset by fault 15.

Fault 7 is hypothetical, based upon stratigraphic data from cores of Goering diamond-drill holes 6 and 7 and U. S. Bureau of Mines diamond-drill holes 95 and 96 (sections I-I' and J-J'). The topographic relief in the vicinity also is suggestive of the presence of this fault.
Fault 8 is hypothetical, presumably trending northeast, based upon stratigraphic evidence obtained from drilling cores (section J–J').

Faults 9, 10, and 11 were found in diamond-drill holes and in the 75-foot level of the Mahoning-Goering shaft (sections D–D', F–F', and G–G'). The trends of faults 9 and 11 arbitrarily are plotted the same as that of fault 10. No surface evidence was found for these faults, probably because the walls of the faults are deeply weathered limestone.

The presence of fault 12 is based upon stratigraphic discrepancies (sections J–J' and K–K') and topographic evidence.

Fault 13 was cut in diamond-drill holes (sections K–K' and L–L').

Fault 14 is a small fracture entirely in sandstone where the drill penetrated it. No mineralized rock was found along it, and its trend is uncertain to the author.

The mapping of fault 15 is based mostly on evidence from diamond-drill cores (sections M–M', N–N', and O–O'). Silicified sandstone cropping out up hill from the junction of faults 15 and 16 is confirmatory evidence.

Faults 16 and 17 may be offset continuations of faults 6 and 2, respectively. Their presence is shown in diamond-drill cores.

Faults 18 and 19 were noted in diamond-drill cores. The projection of these faults to the surface is hypothetical because their dip is unknown.

The location of fault 20 is based upon topographic evidence, but the presence of this fault is indicated by sandstone, probably Bethel, cropping out near Ste. Genevieve limestone. Fault breccia and vein calcite were noted in two small pits along the fault.

Fault 21 is inferred from the offset of the Clay Lick fault, and also from the presence of silicified sandstone along the Salem-Dycusburg road and steeply dipping sandstone beds near the junction of that road with the mine road.

Faults 22 and 23 are entirely within sandstone at the surface. They were traced by exposures of silicified sandstone.

Fault 24 was inferred and traced from the distribution of float of silicified sandstone along the hill slope.

The presence of faults 25 and 26 is indicated by sandstone cropping out close to limestone and shale of the Renault formation.

Fault 27 is inferred from steeply dipping beds of sandstone and sandstone cropping out near the Lloyd shaft, which was sunk in Ste. Genevieve limestone.

The presence of fault 28 is suggested by the juxtaposition of Cypress or Bethel sandstone against Ste. Genevieve and St. Louis limestones.

Underground workings from the Green shaft are on fault 29 (fig. 7). The fault pattern in this area is not clearly understood. Fault 29 dips
northwest in the Green shaft. The cross cut in the footwall at a depth of 77 feet is in cherty limestone boulders, presumably residual from the St. Louis limestone. At the top of a shallow shaft about 100 feet east of the Green shaft (pl. 7), however, sandstone is exposed. Possibly a fault joins fault 29 before reaching the surface; or perhaps a cross fault is subparallel to the road east of the Green shaft. The first interpretation is more probable.

Faults 30 and 31 are cross faults based upon types of waste rock taken from the various pits and shallow shafts.

The presence of fault 32 is based upon evidences of mineralization and fault breccia taken from a shallow shaft and a pit on the side of the hill slope.

**FLUORSPAR DEPOSITS**

**GENERAL FEATURES**

More than 25,000 tons of fluorspar has been produced from the mines and prospects of the Mineral Ridge area. In addition, small quantities of sphalerite, smithsonite, and galena, associated with the fluorspar, have been mined.

The fluorspar came from gravel spar and vein deposits, which are localized along parts of the faults of the area. Most of the ore has come from the vicinity of the John Pace shaft, where levels as deep as 300 feet have been worked.

**MINERALOGY**

The chief minerals in the fluorspar deposits are calcite and fluorite, with subordinate quantities of quartz, sphalerite, galena, smithsonite, marcasite, and pyrite.

The most abundant vein mineral is milky white to gray massive calcite (CaCO₃). Calcite veinlets are also scattered abundantly through the country rock near the fluorspar veins. The boundaries of the calcite veins and veinlets with the country rock are generally sharp, although gradational contacts occur in places. The massive calcite in the veins ordinarily is fractured only slightly. Studies of thin sections, however, show that the calcite is twinned almost invariably.

Fluorite (CaF₂) is the next most abundant vein mineral. It is brown, clear, or light purple. The brown or clear variety occurs where the vein is wide and is composed chiefly of fluorite; the purple variety is common where the fluorite is in small veinlets or aggregates of veinlets. Nearly all of the fluorite is coarse grained. Massive fluorite generally shows a sheeted structure, with bands about half an inch wide; it breaks readily along these bands.

Sphalerite (ZnS) is a common associate of fluorite. It is bright reddish-brown and occurs in small grains or aggregates of grains,
either as veinlets or as scattered disseminations. The sphalerite is associated with the fluorite, and only subordinately with the calcite.

Galena (PbS) is common in the veins and, like sphalerite, is generally associated with the fluorite. Its distribution is much more erratic than that of the sphalerite. The galena ordinarily occurs in tiny imperfect cubes but locally in cubes as large as 1 inch on an edge.

Fine-grained quartz is commonly, although not abundantly, associated with the vein deposits. In thin section, the vein quartz is seen to be a felted or matted mass of small prismatic quartz crystals averaging 0.02 millimeter in length, similar to that described by Currier (1937, p. 384, 385). Locally part of the felted aggregate is composed of a mosaic of strained tiny quartz grains less than 0.001 millimeter in diameter. Fragments of sandstone also are found in the veins. In some samples probably derived from sandstone, the quartz grains are roughly equidimensional, 0.3 millimeter in diameter, and have a granoblastic texture. Parts of this type of siliceous material also are crushed and have a fine-grained cataclastic groundmass with clusters of the equidimensional quartz grains still present, typical of a mortar texture. Some of the rock containing equidimensional-grained quartz has an interstitial filling and coating of a carbonate mineral. Green chlorite, brown tourmaline, and biotite are locally present, suggesting a clastic origin of the siliceous material. A few tiny grains of twinned plagioclase feldspar were seen.

Tiny anhedral grains and cubic crystals of brassy pyrite are common in the fluorspar veins.

Marcasite occurs in a cavity cutting across the vein on the 300-foot level from the John Pace shaft (pl. 8). The cavity strikes northeast, parallel to the drift, and dips 15°–25° SE. The opening ranges in width from 1 to 2 feet; on both walls marcasite forms botryoidal masses with radii of about 2 inches. In polished section, the marcasite is seen to have wavy concentric growth rings. Each growth layer consists of strongly anisotropic blades of marcasite, radiating outward from the center of the mass.

THE VEINS AND ORE BODIES

The veins are commonly a mixture of calcite and fluorite, although either may occur to the exclusion of the other. The veins range in width from less than an inch to 40 feet; vein widths of about 4 feet are most common. In places the veins consist of sheeted coarse-grained brown or clear fluorite, but more commonly calcite is dominant, with small fluorite veins crosscutting the calcite. Sphalerite and galena are widely distributed through the veins, generally associated with the fluorite. Sphalerite locally may constitute as much as 6 percent and galena 2 percent of the vein material.
The contacts of the veins with the country rock are commonly sharp along the footwalls, but along the hanging walls the contacts between the veins and country rock are generally irregular and are marked by series of short en échelon fractures.

Very little information is available on the size of the ore bodies. Most of the mined deposits were residual deposits of fluorite formed by the weathering of the country rocks and gangue minerals near the surface and commonly termed gravel spar; data about them are scarce. Gravel-spar deposits were rarely more than 100 feet deep, 100-200 feet long, and 3-5 feet wide. In the workings of the John Pace shaft and other adjacent caved shafts, the ore body consisting of combined gravel spar and vein material is about 300 feet long, ranges in width from a few inches to 40 feet; it has been mined from the surface to the 300-foot level. Much of the vein is calcite at its wider places.

The grade of the mined fluorspar varied widely. The gravel-spar deposits were high grade, generally containing 60-85 percent of calcium fluoride. About 12,000 tons of ore was mined in 1946-47 from the vein deposit in the John Pace shaft; the ore averaged 45 percent of calcium fluoride, about 3 percent of zinc sulfide, and 1 percent of lead sulfide. Smithsonite is reported to have been mined in the weathered zone from a few shallow pits and trenches along the faults.

**ORIGIN AND LOCALIZATION OF VEIN DEPOSITS**

The relationships of the crosscutting minerals of the vein deposits indicate that quartz and calcite were the first minerals to be deposited. The vein quartz, found as the felted aggregates of prismatic crystals previously described, occurs sporadically as irregular remnants within the veins. Quartz may be the earliest vein mineral, but the evidence is insufficient to prove this conclusively. After a period of fracturing, fluorite filled the fractures and possibly replaced the calcite slightly. Fluorite replaced the country rock on a small scale, but evidence for large-scale replacement is lacking. The occurrence of sphalerite and galena in fractures in the fluorite suggests that the sulfides were the latest minerals to be deposited.

In the Mineral Ridge area few data are available on the localization of the vein deposits within the faults. Study of the workings from the John Pace shaft and the writer's general experience elsewhere in the Kentucky district, however, suggest that the most important factor was availability of space, both for penetration of the solutions and deposition of the calcium carbonate and fluorine. The source of the fluorine, although not definitely known, is assumed to have been magmatic. The calcite, at least in part, however, was probably derived from the country rock limestones.
In the John Pace shaft, the widest part of the vein occurs at the junction of the Woods fault and fault 5. The widening of veins at the junction of faults is common elsewhere in the district.

The control that stratigraphy exercised on localization of the ore is illustrated in a raise from the northeastern part of the 215-foot level of the John Pace shaft. According to the operator, a fluorspar vein between the Renault formation and the St. Louis limestone, was cut off abruptly at the contact of the Renault formation with the overlying Bethel sandstone (pl. 7, section D-D'). A shale bed about 3 feet thick at the top of the Renault formation probably had some influence in controlling the deposition of the vein minerals.

The influence of shale is illustrated also in the northeast face of the 215-foot level of the John Pace shaft (pl. 8). The vein pinches out against shale of the Renault formation. On the other hand, in a stope above the 215-foot level at the junction of the Woods fault and fault 5, a bed of shale about 5 feet thick stands nearly vertical on the hanging wall near the widest part of the vein.

**DESCRIPTION OF MINES AND PROSPECTS**

**RILEY**

The Riley mine was first described by Ulrich and Smith (1905, p. 195-197). The shaft they described was sunk in 1904 to a depth of 75 feet; it is caved now, and a slumped area is the only evidence remaining (pl. 7). A jig mill was built on the property in 1903 but dismantled in 1907. According to local reports, little effort was made to mine fluorspar. Since 1907, several shallow shafts and prospect pits were dug along the Woods fault, and small amounts of fluorspar were mined. Currier (1923, p. 127) reported that the property was in operation in 1920.

Fohs (1907, p. 276) referred to the Riley mine and stated that a 2-inch vein of wad was present in the old original shaft. This report was not verified by the writer.

The Ozark-Mahoning Co. drilled 9 holes on the property in 1946. Hole 4 cut about 6 feet of material containing an average of 35 percent of calcium fluoride and small quantities of zinc and lead. Most of the other holes cut barren fault zones (pl. 7, sections A-A' and B-B'). Fluorspar on dumps from pits along the Woods fault contains typical fluorspar vein material with small quantities of sphalerite and galena.

**MINERAL RIDGE NO. 1**

The first definite mention of mining on the Mineral Ridge No. 1 property was made by Currier (1923, p. 128), who briefly described the prospect of the Farris Fluorspar Co. The old Woods prospects
(Norwood, 1876, p. 465-469), however (mentioned below under a description of the Goering property), possibly may be on the Mineral Ridge No. 1 property.

Muir (1947, p. 3-4) described the general history of development on the property up to the time of the work by the Ozark-Mahoning Co. in 1945. Muir also described the results of a U. S. Bureau of Mines diamond-drilling program in 1945 on the property.

The Mineral Ridge No. 1 property has produced most of the ore mined from the Mineral Ridge area. Nearly all of this ore has come from the northeastern part of the property. Production data before 1937 are not available. Between 1937 and 1941, however, about 3,500 tons of fluorspar was mined. In 1944, Mr. Diffie of Tulsa, Okla., leased the property and put down 2 diamond-drill holes (pl. 7). The Ozark-Mahoning Co. from 1945 to 1947 produced about 12,000 tons of ore containing an average of 45 percent of calcium fluoride, 3 percent of zinc sulfide, 1 percent of lead sulfide, 30 percent of calcium carbonate, and 20 percent of silica. The mine was subleased to the Alco Lead Co. in November 1947.

Shafts and pits have been dug at various sites on the property, particularly near the northeast end. Little information is available about the work southwest of the John Pace shaft, with the exception of a 40-foot shaft sunk in 1947 about 20 feet southeast of U. S. Bureau of Mines diamond-drill hole 105. The shaft went through limestone boulders and a few veinlets of calcite and fluorite, but no ore deposits were found (pl. 7, sec. 0-0').

The Luther Pace and Old shafts were inaccessible at the time of the field work, but A. H. Reed, Sr. (oral communication), states that the Luther Pace shaft was sunk 60 feet, and a short crosscut was made at a depth of 25 feet; about 8 inches of fluorite was cut. The upper 30 feet of the shaft was sunk in Cypress sandstone and the lower 30 feet in shale and shaly limestone, probably belonging to the Paint Creek shale. The Old shaft (now caved) was 185 feet deep with levels at depths of 100, 150, and 185 feet. Most of the ore from the entire Mineral Ridge area before 1945 was made from these workings. A considerable quantity of the ore probably was gravel spar.

The John Pace shaft (pl. 8) was sunk to a depth of 130 feet in 1941, after the Old shaft had caved. A crosscut was driven to the vein, which consisted of a wide zone of calcite and limestone breccia with scattered fluorite veinlets. Bethel or Cypress sandstone is present at the northwest end of the crosscut, and St. Louis limestone is present to the southeast on the footwall.

In 1945, the Ozark-Mahoning Co. sank the John Pace shaft to a depth of 215 feet and sank a winze from that level to a depth of 300 feet (pl. 8). Most of the 12,000 tons of ore shipped from the property
from 1945 to 1947 by the Ozark-Mahoning Co. came from these levels. The country rock in the crosscut on the 215-foot level and the footwall of the Woods fault along the southeast side of the drift is St. Louis limestone. In the southwestern part of the workings, the Renault formation and Bethel sandstone are present on the hanging wall. To the northeast, the Renault formation is exposed on the hanging-wall side, as a result of cross faulting. The zone of widest mineralized rock and vein material is near the junction of the Woods fault and fault 5.

On the 300-foot level, the footwall of the Woods fault is St. Louis limestone and the hanging wall is the Renault formation.

GOERING

The original prospects in the Mineral Ridge areas mentioned by Norwood (1876, p. 19-21) were the Henry and Robert Woods shafts, probably on the Goering property. The Hodge prospect mentioned by Ulrich and Smith (1905, p. 195) is possibly on this property also. Currier (1923, p. 127-128) mentioned shallow workings of the Giant Mining Co.

Few production data are available for the Goering property. In 1917, about 125 tons of fluorspar was mined. Lessees probably have mined a total of a few hundred tons of fluorspar at various intervals.

Operations on this property generally have been in the western part near the Wallace property and in the central part. Most of the mining has been on a small scale, as the shafts are 50 feet or less in depth.

The Ozark-Mahoning Co. drilled 8 diamond-drill holes (pl. 7) late in 1946. In 1947, the Mahoning-Goering shaft was sunk to a depth of 75 feet (section $F'-F'$), and some fluorspar was mined from a level at that depth. Later the shaft was sunk to a depth of 125 feet, but little mining was done.

WALLACE

The Wallace (Pierce) property was not operating during the time of the writer's field work, and information about it is meagre. Most of the work on the property was done in the northeast corner, near the Goering and Mineral Ridge No.1 properties.

The first mention of the property probably was by Ulrich and Smith (1905, p. 195), who referred to it as the Henry Hodge prospect. The writer is uncertain whether Ulrich and Smith were referring to the workings on the Wallace property or on the Goering property.

Hoeing (1913, p. 65) noted that zinc carbonate was being mined in 1913 from the A. J. Pierce property.

Small-scale mining operations were conducted during World War I, according to local reports, and shortly afterwards according to Currier (1923, p. 127, 128).
OPEN CUT NORTHEAST OF JOHN PACE SHAFT
Mineral Ridge No. 1 property. View looking northeast along Woods fault, 1944.
The last mining operation on the property was about 1930 when the Wallace Fluorspar Co. sank a shaft to a depth of 130 feet near the Goering property line. Considerable gravel spar and some galena are reported to have been found. This shaft could not be identified in the field by the writer.

**MARTIN**

Ulrich and Smith (1905, pl. 8) show the location of the Tom Martin prospect on their geologic map. Fohs (1907, p. 228) mentioned that the Martin prospects were operated by C. and A. T. Pope in 1904 and that J. A. Clark had started prospecting on the property in 1902.

Since 1904 small-scale mining operations have been conducted at intermittent intervals and small quantities of gravel spar have been mined. The shafts were probably no more than 50 feet deep.

**KELLY**

No large-scale mining has taken place on the Kelly property or on other properties southwest of the Salem-Dycusburg road. Gravel spar and some smithsonite and galena have been mined from several shallow shafts and pits on the Kelly property. Few historical or geologic data are available for this property.

No records are available of production from the Kelly property. According to A. H. Reed, Sr., Mr. Kelly Spradling mined a little fluorspar during World War I. In 1944 Mr. Ray Jennings sank a shaft to a depth of 100 feet (pl. 7). The U. S. Bureau of Mines put down one diamond-drill hole in 1945 (Muir, 1947, p. 6, 9).

**BILLY OWL**

The first work on the Billy Owl property known to the writer was done in 1935 and 1936 when the Pugh No. 1, Pugh No. 2, and Billy Owl shafts were operated. The depths of these shafts are 30, 60, and 125 feet, respectively.

No production data are available for the Billy Owl property. A small quantity of gravel spar with a little galena has been produced from the various shallow pits and shafts.

When James Steele Williams of the Geological Survey visited the Billy Owl shaft in November 1942, the shaft was about 125 feet deep with short crosscuts and drifts at depths of 72 and 115 feet. On both levels low-grade purple and honey-yellow fluorite with a little galena occurs in a matrix of clay and calcite boulders.

**GRASSHAM NO. 3**

Very little prospecting has been done on the Grassham No. 3 property. The Lloyd shaft was sunk during World War II to a depth of 30 feet in Ste. Genevieve limestone. The waste dump at the shaft
contains white calcite with small streaks of purple and colorless fluorite and traces of galena and sphalerite.

GREEN

According to local reports, some gravel spar was mined in 1919 from the trench in the western part of the Green property (pl. 7). The Green mine (fig. 7) was started about 1929 by a Mr. C. E. Townsend. About 400 tons of fluorspar was mined between 1929 and 1936 from the upper level and shaft. In 1940, Mr. C. N. Pugh of Sturgis, Ky., sank the shaft to a depth of 130 feet and drove crosscuts and drifts at depths of 100 and 130 feet.

The 77-foot and 100-foot levels were driven in gravel spar that ranged from 4 to 20 feet in width. High-grade gravel spar about 2 feet wide was seen by Russell in the faces on the 77-foot level. Two zones of gravel spar, each about 4 feet wide, were found on the 100-foot level. The 130-foot level is below the weathered zone; the vein is solid and is composed of a calcite-limestone fault breccia with traces of fluorite. The Green mine is a typical example of a low-grade vein deposit that was concentrated by weathering to a high-grade, although small, deposit of gravel spar.

RYAN

According to Messrs. Robert and Richard Reed of Paducah, Ky., about 30 tons of high-grade gravel spar was taken in the fall of 1942 from a 30-foot shaft (now filled) on the Ryan property just south of the Reed shaft (pl. 7).

Because of bad ground the 30-foot shaft was abandoned, and the Reed shaft was sunk to a depth of 86 feet. Crosscuts were driven in four directions at a depth of 60 feet, but no fluorspar was found.
Bedrock Boulders and clay to Ste. Genevieve limestone in Bedrock Boulders and clay with St. Louis limestone in Bedrock Boulders and clay in Undifferentiated limestone Boulders and clay in Undifferentiated sandstone in Gravel spar in Fluorite in clay matrix in Calcite-limestone breccia with traces of fluorite in Shaft above and below levels in Lagging along drift

From pace and compass survey, 77 level by R.D. Trace September 1943, 100 and 130 level by R.T. Russell, May 1945

FIGURE 7.—Map of underground levels of the Green Mine, Mineral Ridge area, Livingston County, Ky.
LITERATURE CITED


Weller, Stuart, and others, 1926, Map of the areal and structural geology (fault pattern) of Livingston County: Kentucky Geol. Survey, ser. 6.

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INDEX MAP AND LONGITUDINAL PROJECTION, SHOWING FLUORSPAR DEPOSITS OF THE CENTRAL PART OF THE COMMODORE FAULT SYSTEM, CRITTENDEN COUNTY, KENTUCKY
EXPLANATION

Caseyville sandstone
Kinkaid limestone
Degonia sandstone
Clore limestone undifferentiated
Palestine sandstone
Menard limestone
Waltersburg sandstone
Hardinsburg sandstone
Golconda formation
Cypress sandstone, Paint Creek shale, and Bethel sandstone, undifferentiated
Cherokee formation
Ste. Genevieve limestone
St. Louis limestone
Spergen and Warsaw limestones, undifferentiated
Limerick formation

Undifferentiated material of fault zone

Fault, showing dip; dashed where approximately located.

Indefinite contact

U, upthrown side: D, downthrown side

Strike and dip of beds

Horizontal beds

Shaft

Caned staff

Prospect pit

Opencut or trench

D.D.H.

Diamond-drill hole

Concrete property line marker

Bench mark at Salem, Kentucky