1911

Fluorspar mining in Kentucky

Walter Coffran Richards

Follow this and additional works at: http://scholarsmine.mst.edu/professional_theses

Part of the Mining Engineering Commons

Recommended Citation

This Thesis - Open Access is brought to you for free and open access by the Student Research & Creative Works at Scholars' Mine. It has been accepted for inclusion in Professional Degree Theses by an authorized administrator of Scholars' Mine. For more information, please contact weaverjr@mst.edu.
FLUORSPAR MINING IN KENTUCKY

by

Walter Coffran Richards.

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

DEGREE OF

ENGINEER OF MINES

Holla, Mo.

1911.

Approved by

Assistant Professor of Mining
FLUORSPAR MINING IN KENTUCKY

by

Walter Coffran Richards.

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

DEGREE OF

ENGINEER OF MINES

Rolla, Mo.

1911.

Approved by

C. W. Forbes

Assistant Professor of Mining
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS.</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction.</td>
<td>1</td>
</tr>
<tr>
<td>Mining Districts.</td>
<td>1</td>
</tr>
<tr>
<td>Statistics on Production.</td>
<td>2</td>
</tr>
<tr>
<td>Uses of Fluorspar.</td>
<td>3</td>
</tr>
<tr>
<td>Geography and Topography.</td>
<td>4</td>
</tr>
<tr>
<td>History.</td>
<td>6</td>
</tr>
<tr>
<td>Mines and Mining Operations.</td>
<td>6</td>
</tr>
<tr>
<td>Most Important Mines.</td>
<td>10</td>
</tr>
<tr>
<td>Geology.</td>
<td>14</td>
</tr>
<tr>
<td>General Statement.</td>
<td>14</td>
</tr>
<tr>
<td>Stratigraphy.</td>
<td>14</td>
</tr>
<tr>
<td>Faulting.</td>
<td>16</td>
</tr>
<tr>
<td>Occurrence of Ores.</td>
<td>17</td>
</tr>
<tr>
<td>Genesis of Deposits.</td>
<td>21</td>
</tr>
<tr>
<td>Development of American Fluorspar Mining Co's</td>
<td></td>
</tr>
<tr>
<td>Mine.</td>
<td>23</td>
</tr>
<tr>
<td>General Description.</td>
<td>23</td>
</tr>
<tr>
<td>Conclusion.</td>
<td>33</td>
</tr>
<tr>
<td>Bibliography.</td>
<td>35</td>
</tr>
</tbody>
</table>
LIST OF ILLUSTRATIONS.

Page.

Yandell opencut and buildings....................... 13
Specimens of fluorite showing banded structure
and galena crystals.............................. 16
Specimens of fluorite showing crystallization,
also No. 1 lump, and transparent crystal. 20
Mine of the Am. Fluorspar M. Co. .................. 25
Washing spar by sluice method...................... 29
Specimens of fluorite showing slickensiding,
spar and zinc, and flint cemented by spar. 30

Plates following body of Thesis:

I. Map of Kentucky Fluorite District
II. Fluorspar Washers
III. Table of Formations
IV. Property of the Am. Fluorspar M. Co.
V. Timbering Practice
VI. Map of 90-foot Level
VII. First Shaft House and Machinery
VIII. Shaft House of the Am. Fluorspar M. Co.
IX. Map of 150-foot Level
X. Turntable for Wooden Track
XI. Maps of 165 and 180-foot Levels
XII. Sketch of Probable Conditions at the
     Mine of the Am. Fluorspar M. Co.
FLUORSPAR MINING

In

KENTUCKY.
INTRODUCTION

The mining of fluorite, or fluorspar in western Kentucky is one of the chief mineral industries of that State. As the number of mines and prospects is very great, a thorough treatise on the geology, mines, and methods of this district would make a large volume. This thesis will deal, however, with only a small part of the district, in which the mine operated by the author is located.

Before going into detail, it might be well to mention a few points relative to the fluorspar industry in general. To the average person, fluorspar seems to be unknown. In fact, the knowledge of this mineral is practically limited to members of the mining profession, and those actively engaged in the making of iron and steel and a few other manufactured products.

MINING DISTRICTS

Western Kentucky and Southern Illinois comprise the only section in the United States producing fluorspar in any quantity. The other States in which fluorspar is mined, are Arizona, New Mexico, and Colorado, which produced altogether in 1909 about 1000 tons. England is the largest producer of fluorspar in the world,
where it occurs as a by-product from her lead mines.

STATISTICS ON PRODUCTION

The world's production of fluorspar for 1909 was about 96,000 tons, of which about 45,000 tons was mined in England, and 50,742 tons in the United States. Of this amount, 7,800 tons came from Kentucky. Instead of importing 20,000 tons as in 1908, only 6971 tons were imported in 1909, valued at $26,377.

The production in 1907 was 21,058 tons, but dropped to 6,323 tons in 1908, the year of the money panic. The improvement during 1909 was not as great as was expected, but 1910 brought renewed activity; and a marked increase will be noted when the figures for the year are published.

Mined for almost nothing, shipped to the United States as ballast, it could be had for $4.00 or $4.50 per ton at Pittsburg. Naturally this kept the price of the home product down until the last Congress placed a tariff of $3.00 per ton on imported fluorspar. Now the Kentucky spar sells for $6.50 or $7.00 f. o. b. cars at the mines. This price is for the fluxing grade. The higher grade, when ground to flour, which is used in the manufacture of hydrofluoric acid, sells as high as $12.00 to $14.00.
USES OF FLUORSPAR

The chief use of fluorspar is in the basic open-hearth process of steel manufacture. The advantages gained by its use according to F. Julius Fohs are - (1) slag is more fusible, basic, and liquid; (2) fusion is effected at lower temperature; (3) the concentration of the slag increases the metal output.

While a chemist for the American Steel Foundries, the author noticed that fluorspar was not a regular part of the "charge" to the furnaces. It was used sparingly and by the shovelful, and only when the "heat" was giving trouble on account of too much phosphorus. The tendency is towards a more general use of this flux, however, as it helps, when used judiciously to open up and liquify the slag, so it will retain and carry off the impurities. The charge of fluorspar varies considerably, but was never noted over 600 pounds to a 25-ton heat. An average of 600 heats recorded during December, 1908, and August, 1909, gives 83.3 pounds per heat. In 100 of these heats no fluorspar was charged. Mr. Fohs recommends the use of 3 pounds of spar to every 100 pounds of limestone, to get the best results. This foundry, however, made very good steel on a mixture of 3.6 pounds of spar to 300 pounds of limestone per ton of steel made. Its value depends on the liberation of
CaO which takes care of additional silica. The reactions would be as follows:–

\[2 \text{CaF}_2 + \text{SiO}_2 = 2 \text{CaO} + \text{SiF}_4\]
\[2 \text{CaO} + 2 \text{SiO}_2 = 2 \text{CaSiO}_4\]

or written together we would have:–

\[2 \text{CaF}_2 + 3 \text{SiO}_2 = 2 \text{CaSiO}_3 + \text{SiF}_4\]

Limestone and silica react thus:–

\[\text{CaCO}_3 + \text{SiO}_2 = \text{CaSiO}_3 + \text{CO}_2\]

Written together:–

\[2 \text{CaF}_2 + \text{CaCO}_3 + 4 \text{SiO}_2 = \text{SiF}_4 + \text{CO}_2 + 3 \text{CaSiO}_3\]

The steel foundries consume about 80% to 85% of the fluorspar used. It is also used in the manufacture of hydrofluoric acid, glass, enamel, and sanitary ware, electrolytic refining of antimony and lead, and the production of aluminum.

**GEOGRAPHY AND TOPOGRAPHY**

The Kentucky district covers the area bounded by the Ohio, Tradewater, and Tennessee Rivers, and includes the Counties of Crittenden, Livingston, Caldwell, and Lyon. The term "Kentucky-Illinois Fluorite District" includes, in addition to the above, the Counties of Pope and Hardin just across the river in
southern Illinois.

The surface of this area is generally rolling and irregularly broken, especially along the stream courses. A few comparatively level tracts occur, but these are always of small extent. The irregularities are due chiefly to the conditions resulting from the extensive faulting that this district has undergone. None of the characteristic formations resulting from simple faulting reach normal development, but, instead, a combination of types is found. The down-thrown rocks which, at first, must have formed depressions are now found as hills and ridges, due to the varying effects of erosion on rocks of different degrees of hardness. For this reason it is most difficult to interpret surface indications. In one fifteen acre tract, three faults are known, or supposed to cross, but only one can be traced on the surface, and that with difficulty. Plate I shows how closely faulted this area is. Although primarily a farming country, most of it is poor farm land, as the residue of the sandstone hill-cappings washes easily leaving ridges and gullies that make cultivation almost impossible. About one-fourth to one-third of the land is still thickly wooded.
HISTORY.

According to Mr. E. O. Ulrich of the U. S. G. S., the first attempt to mine fluorspar "was made by a company headed by President Andrew Jackson", their shaft being sunk within a hundred yards of a recent producing mine. Other attempts were made before the Civil War, but none proved to be successful.

MINES AND MINING OPERATIONS.

The first mining was done for lead, and by very crude methods. There are also rumors of mining for silver, although repeated analyses have shown only traces of silver in the lead. The first fluorspar was shipped from the Yandell mine about 1873, and the following year from the Memphis. These are the two oldest authentic mines on record. The Yandell ceased to produce about five or six years ago, but explorations during 1910 showed the presence of more fluorite at greater depth. The Memphis mine is still in operation.

The Yandell spar was shipped in barrels by boat, as it is only four miles from the Cumberland River. Very little development was done until about 1900. Since then methods have improved and new properties opened, until now, with the tariff of $3.00 per ton, fluorite mining is a profitable industry.
Although mines and prospects are to be found on almost every fault, only those larger ones near the American shaft are shown on Plate I. The maps on this plate are from surveys and maps made by Ulrich and Smith.

The deposits are encountered near the surface and frequently outcrop. A depth of 500 feet is seldom reached, and few shafts are over 200 feet in depth. Horse whims are common sights although most producing mines now use six to ten horsepower steam hoists. The shafts are of only one hoisting compartment and average four feet by six feet or five feet by seven feet in the clear. Many of the older workings were open cuts with walls poorly stulled. What levels were run were poorly timbered and in a few years fell in, thereby increasing the cost of extracting ore lower down. The best grade was naturally mined first, leaving the lower grades to be taken out later when higher prices warranted. The writer was impressed, on his first visit to this district, by the numerous scars remaining here and there, where ore had been gouged out as cheaply as possible and the mine then left to take care of itself. Even the best of the mines present a shabby appearance and would not impress a visitor. The cost of mining varies as in other fields, according to water encountered, waste handled, and
hardness of walls and vein, from 75¢ to $3.00 per ton. Four men with a whim, working in a dry gravel vein could mine spar almost as low as fifty cents per ton.

After mining, a part or all of the ore must be washed to prepare it for market. Two methods are in general use; - the sluice, trough, or gravity washer, as it is variously called, and the log washer. The logs are best for dirty spar, especially when it contains lumps of clay, and the trough for cleaner ore and hurried work. The costs vary from twenty to seventy five cents depending on the impurities and rapidity of washing. A detailed description of these two methods, as well as a good general description of the mining practice, may be found in "Fluorspar Deposits of Kentucky," Kentucky Geol. Survey Bulletin No. 9, 1907, by F. Julius Fohs. Plate II shows the plans and elevations of these two types of washers.

For mines situated away from the railroad, the transportation by wagon of the ore to the cars is a bigger item, than it would at first appear to one uninitiated. I know of very few roads, or even parts of roads, that could be called good, and at some seasons all roads are impassable. A good four-horse team may haul 5000 to 6000 pounds for a while, but it wears them out. 1200 pounds per horse is a very good average. The hauling is
done by contract and costs per ton

about $0.80 for 4 miles
1.00 " 5 "
and $2.00 to $3.00 " 8 to 10 "

This does not include weighing or loading. Weighing costs 5 cents per ton, and loading 10 to 20 cents.

Freight rates show a discrimination against Kentucky, which hurts the shipper to some extent; although prices are usually, if not always, quoted f.o.b. cars at the shipping point. This, in some cases, amounts at as much as 90 cents a ton, as shown by these figures.

<table>
<thead>
<tr>
<th>Location</th>
<th>Pittsburgh</th>
<th>E. St. Louis</th>
<th>St. Louis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois points</td>
<td>$0.10 or less</td>
<td>.06</td>
<td>.06 /100#</td>
</tr>
<tr>
<td>Kentucky</td>
<td>&quot;</td>
<td>.11 or less</td>
<td>.08</td>
</tr>
</tbody>
</table>

These figures also show the advantage East St. Louis has over St. Louis, as a result of the Terminal monopoly.

Fluorspar is graded at the mine according to size and quality. All over 1 to 2 inch mesh goes as lump, and the undersize as gravel. No sharp division is made, however, and the size varies with different mines. That lump, which is white and contains the highest percentage of calcium fluoride, often over 99.5%, is sold for grinding, and is used in the manufacture of hydrofluoric acid. This is worth from $10.00 to $15.00 per ton. Poorer grade lump is usually sold along with gravel to be

Note:- Above rates are taken from the Illinois Central R.R.'s tariff sheet 1382-D, July 14, 1910.
used as a flux in the open-hearth steel process. This grade now sells for $6.00 to $8.00 per ton. (Latest quotations).

**MOST IMPORTANT MINES.**

E. O. Ulrich and W. S. Tangier Smith in "The Lead, Zinc, & Fluorspar Deposits of Western Kentucky", U.S.G.S. Professional Paper No. 36, give detailed descriptions of almost every mine in the district, but only a few points relative to the most important will be given here.

The Memphis and Klondike mines, now owned and operated by the Kentucky Fluorspar Company, are two of the oldest and largest producers. They are situated five miles N. W. of Marion on one of the main N. E. and S. W. faults. Both walls are St. Genevieve limestone. These mines were first opened for lead. As high as 800 tons of fluorspar a month has been mined. They are opened on one of the best defined veins averaging three to four feet.

The Columbia mine, about five miles due west of Marion is about the oldest, and was at one time one of the most important in the district, was originally a lead mine. It was abandoned twice on account of water and when visited in 1910 it appeared to have been shut
down for several years.

The Jim mine about a mile S. E. of the Columbia is important, as it is a zinc mine in amongst all the spar mines. The ore is in contact with a narrow peridotite dike. This mine was opened in 1901 and mined by opencut only, on a vein five to ten feet wide. By 1910 this mine had been abandoned and reached a tumble-down condition. During that year lesers reported a new strike, but of no great importance.

The Tabb fault about twelve miles south of Marion gives us a group of large producers, and is the vein on which the American shaft is sunk. The fault is really a series of faults arranged "en echelon", and separates Birdsville and St. Louis formations. The Tabb mine is a series of shafts from which much rich ore has been taken. It was forced to close down on account of water but during 1910 new shafts were started and when last visited, it was again a good producer.

The Wheeler mine, about a half mile west of the Tabb was abandoned on account of water. Just west of the Wheeler is the Wheatcroft, which was purchased and reopened by a Birmingham Company, but without much success.

About a mile and a half from the Tabb mine, are the two Asbridge shafts. The older one was a
good mine but has been worked out. The new shaft is an excellent producer now, the author having seen the vein 20 feet wide in places. The next mine directly west is the Pogue, which is reported to have produced 800 tons a month during 1903; but was later abandoned on account of a slide of watery spar which took the shaft.

About a half mile from the Pogue we find the Parish mine which is now sinking its third shaft within a distance of 100 feet. They have good spar but poor workmanship has caused the loss of two shafts. This brings us to the property leased by the American Fluorspar Mining Company which will be described later. Not 300 yards farther west is situated the Kentucky shaft, which has been another good producer. Bad ground also caused the loss of this shaft. It was reopened during 1910, only to be closed down again, after a serious accident.

The last mine along this line is only a quarter mile away, but proves to be on another fault. The Yandell mine is a series of shafts and open cuts opening the vein for about 1000 feet. This mine was one of the very best. The accompanying photograph shows the opencut and buildings as they appeared in 1909. (See page 13)
About two miles N. W. of these mines is the Hodge, which was also one of the big producers. Mining was done from both shafts and opencuts. It is now closed, although good spar is reported at the bottom.

In addition to these mentioned there are over 150 others of varying degrees of richness, scattered thickly over the District. From the above it will be

Yandell Opencut and Buildings.

noticed that an over abundance of water has caused the downfall of more than one company. Kentucky is noted for its caverns, and many underground streams are found in this area.
GEOLOGY

GENERAL STATEMENT

The rocks encountered on the surface and underground in this district all belong to the Lower Carboniferous or Mississippian series, except near the Tradewater River, where remains of the Pottsville formation may be seen. Faults are so numerous over this area that the surface is broken up into many irregular blocks showing different exposures.

STRATIGRAPHY.

Plate III gives the Table of Formations which will be described, with their chief characteristics. The lowest formation shown is the top of the Devonian series, and is only seen in two small outcrops on the Illinois side of the Ohio River. The lowest Carboniferous formation, comprising what is known as the Tullahoma, is also rare in the Kentucky district. In Illinois it is 200 to 250 feet thick.

The St. Louis limestone is the next formation and its exposures form about one-third of the area of the district. It is dark gray and highly silicious. The limestone is easily decomposed liberating quantities of chert. The chert is dense and ball-like and is characteristic of this formation. The St. Louis limestone
has a thickness of about 500 feet.

Next above the St. Louis limestone is the Chester group, comprising the Princeton or St. Genevieve series, the Cypress, and the Birdsville formations. The St. Genevieve formation is divided into three members:—
a white and blue oolitic limestone called the Fredonia oolite, a calcareous and laminated sandstone called the Rosiclare sandstone, and a variable shaly limestone, known as the Ohara limestone. Where this formation is at the surface, are found the valleys best suited for agriculture. Sink holes are also found as in the case of St. Louis limestone exposures.

The Cypress sandstone is a light red-brown, quartzose sandstone, massive and usually close grained. When exposed in creek beds it is broken into oblique blocks. This sandstone is 50 to 100 feet thick.

The Birdsville formation is the top member of the Chester group and is a variable series of shales, limestones, and sandstones. The sandstones form about one-half of the total thickness, and vary from quartzites to calcareous sandstones. The limestones and shales are also extremely variable in color, texture, and structure. The total thickness varies from 500 to 700 feet.

The Mansfield sandstone of the Pennsylvanian period is found along the Tradewater River and
as a capping on some of the higher hills.

FAULTING

E. O. Ulrich reports no less than 35 faults, with a displacement of from 300 to 1400 feet, over this area. In general direction they run N. E.

Specimens of fluorite: (a) showing banded structure (b) containing galena.

and S. W. veering to east and west. Similarity of opposing formations and weathering make them very difficult to trace. The lines of their general direction when seen on the map take the shape of a fan. These radial faults are the result of a doming action, centering along the Ten-
nessee River. Igneous matter did not come to the surface at this point, but farther north several igneous dikes are found. This movement occurred after the Carboniferous Era, as all the formations are seen faulted and some veins show evidences of a much later secondary faulting. The average dip of these faults is about 75° to 85°.

Most of these faults are filled with veins chiefly in the St. Genevieve, St. Louis formations. Their width varies from nothing up to 15, and in some cases 20 feet. The walls are usually well defined and often slickensided. Slickensiding also occurs within the vein, and a banded structure, supposedly due to pressure, is often seen. (See photograph on page 16). Limestone walls are fractured and filled with calcite and fluorite seams, usually calcite. The depth to which these veins go has not been determined.

OCCURRENCE OF ORES.

The ideal vein would consist of massive crystalline fluorite from wall to wall, but this is found in only a few places. Country rock, other minerals and variations in the structure of the fluorite are more commonly seen. Loose gravel spar is found beside massive spar, and sometimes clay comes between the two. Clay
often takes the place of the entire vein for a number of feet. Shoots of mineral within the vein are common. A banded structure is often seen where the bands are of different shades of violet, and sometimes layers of galena crystals form bands at the same time. Calcite is also common and will sometimes replace the vein, as the clay does.

The minerals more commonly found associated with fluorite are galena, sphalerite, calcite, barite, smithsonite, pyrite and quartz. Among those more rarely found are cerrucite (PbCO₃), pyromorphite (PbCl) Pb₄ (PO₄)₃, sulphur (S), zincite (ZnCO₃·2Zn(OH)₂), calamine (H₂Zn₂SiO₅), greenockite (CdS), limonite (2Fe₂O₃·3H₂O), chalcopyrite (CuFeS₂), malachite (CuCO₃·Cu(OH)₂), kaolinite (H₄Al₂Si₂O₉) and wad, an oxide of manganese. This manganese in some localities gives traces of cobalt and nickel.

Galena occurs in irregular crystals of varying sizes up to one-half inch in diameter, as scattered grains and as aggregates. It is sometimes found in such quantity as to pay as a by-product. Sphalerite occurs usually as small grains replacing fluorite and limestone, in and adjacent to, the vein. It is of common occurrence and in some mines is saved as a by-product. Smithsonite is also found replacing limestone, and in
one case, the Jim mine, constituted the entire vein. Pyrite is found in small grains in seams in the limestone and fluorite. Limonite is common in some localities, being found by the author in stalactitic and botryoidal forms.

With the commoner minerals we are familiar, but there are many who do not know what fluorite is, and for what it is used. Fluorite, fluorspar, or spar, as it is commonly called in the district is the fluoride of calcium. Its crystalline habit is cubic, but the faces are often rough on account of irregular development. The more perfect crystals are found lining cavities in the vein. The photograph on page 20 shows such a group of crystals. Penetration twins are often found as well as combinations of the cube with the octahedron. It is brittle and has a perfect cleavage - a sharp blow on the corner of a cube will break off the corner, showing an equilateral triangular cleavage plane. Its usual forms are massive granular, and loose gravel. The lustre is vitreous and all colors are found from pure white, through amber, green, brown, pink, lavender, and violet to smoky and almost black. It is translucent, although some specimens are transparent, and print can be read through an inch or more of crystal, as shown by the photograph on page 20. A friend reports
selling such a piece to a lens manufacturer for several dollars.

The source of color has not yet been fully determined. No traces of metallic oxides have been found. Some attribute the brown color to contained hydrocarbons and the purple color to oxidation.

Specimens of fluorite: (a) No. 1 white lump, (b) cubical crystals, (c) transparent fluorite crystal.

There is a strong odor of coal oil emitted from freshly broken spar which shows the presence of hydrocarbons. From the occurrence of the purple spar near the surface and along water channels, we would think that perhaps that would explain its color.
So far the mines are not deep enough to determine whether or not there has been any secondary enrichment. Neither has any data been gathered on the weathering of the deposits. Ulrich gives the order of removal by solution as follows:-(1) sphalerite; (2) calcite; (3) galena; (4) barite. As the mines have not been developed much below ground water level, examples of the leaching of sphalerite are about the only ones noted. There are many underground caverns and channels, into which surface streams disappear, to come to the surface again at some distance. Water level is reached at about 100 feet.

GENESIS OF ORES.

On the genesis of the fluorite deposits, there are two theories advanced:-

(1) Since they contain lead and zinc, their origin is considered as similar to the lead and zinc deposits of the Mississippi Valley, i.e. segregations from the surrounding rocks by the action of underground waters.

(2) The presence of large quantities of fluorite, rarely found in the Mississippi Valley; the structural features of the ore bodies; and the presence of igneous rocks in the vicinity, suggest genetic relation between the ores and igneous rocks.
It is of interest to note here that the dikes are of the same type as those found in the English fluorite district - the only other large fluorite deposit known.

Ries says, "In unaltered limestone it (fluorite) is exceedingly rare, and the only commercially important deposits found in limestone, are in areas of igneous intrusions." He also says, "It is not an uncommon constituent of many igneous rocks, and enters into the composition of some minerals, such as apatite, and certain micas."

All writers agree that the deposits are from solution, but differ as to the source of the minerals. Some claim one of the limestones as the source, saying that since sea water contained fluorine, barium, lead, and zinc, it must have been transmitted through marine plants, shells, and corals, and the concentrating solutions. The author would think that the preponderance of fluorine in these deposits over lead, zinc, and barium would require a different explanation.

On the other hand, while it is not claimed that the fluorite veins are derived directly from the igneous dikes, the author thinks that a larger mass of magma, of which the dikes themselves are a part, underly this area, furnished the fluorine for the deposits.
These dikes contain two fluorine bearing minerals, biotite and apatite. This theory is strengthened by the fact that the fluorite deposits of Colorado are found in gneisses and granites, which have been intruded by igneous dikes. In New Mexico, also, the fluorite deposits are found near igneous intrusions.

DEVELOPMENT OF AMERICAN FLUORSPAR MINING CO'S MINE.

As a further study and explanation of the methods employed, the author will describe the development of the American Fluorspar Mining Company's property, of which he was superintendent. This mine was developed from a prospect; many college theories were tried, and a number of ideas of our own were worked out.

GENERAL DESCRIPTION.

The "patch of ground" contains a little over 14 acres, on which the company holds a 10 year lease. It is situated in Crittenden County, about 5 miles by wagon from Mexico, the shipping point on the Illinois Central Railroad, and 4 miles from Dycusburg on the Cumberland River. The land lays on the line of a fault vein that has been opened up at several points for over two miles. There had already been 16 shafts sunk and good ore found, although 3 shafts located close together show
a barren place in the vein. Four of the best mines in the district are located here - the Tabb, Asbridge, Pogue, and Kentucky; the Kentucky mine adjoining our property on the west. This Kentucky had been a good producer until about 1908, when it was closed down. During 1910 it was reopened and a quantity of very good gravel spar was taken out. But this spar was so much like quicksand, that it could not be handled safely and the mine was again closed. It was later learned that about 1907 much spar was taken from a level that crossed into our property, which was leased by them at that date. Just across the road, our eastern boundary, are 3 shafts, in all of which spar was found, but no regular vein was opened, only pockets. Plate IV is a map of the property, and shows the location of the shafts and the probable course of the fault veins.

As it was impossible to spend the first 2 or 3 months on the ground, the shaft was started on a contract at $5 per foot, and sunk to 93 feet. Much valuable data concerning rock formations encountered was thereby lost, through the ignorance of the contractor. He reported passing through beds of quartzite and limestone, which were probably boulders, as the walls proved to be over 50 feet apart. The contractor set up a whim which remained as motive power while the first levels
were run. It is cheap power for shallow work costing only $1.75 for man and horse, the driver dumping and wheeling away ore and waste. The photograph on this page shows the mine at this stage.

When the author took charge, he found good men hard to get, supplies high in price, and that the community in general were antagonistic toward strangers and new enterprises. Teamsters would haul spar only at their own price, and the best contract that could be made was for $1.00 per ton for hauling and weighing and 25 cents more for yarding and loading into cars. The price of timbers and lumber, however, was fairly reasonable.
The shaft was of the average size, 4 by 6 feet in the clear, divided down the center by a partition into a hoisting, and ladder way. Plate V represents the timbering practice in shaft and levels. A set of four 6 by 8 inch hewn ring timbers cost $1.20, and were spaced 4$2$ feet apart with 1$2$ by 6 inch corner boards. A second set of corner boards were put on later. The walls were lagged tight with 1$\frac{1}{2}$ inch lagging. At each ring timber, a 4 by 8 inch timber was set crosswise 3 feet from the end, to brace the set and support the lining. Stulls 4 inches square were placed in each corner to brace the timbers vertically. The hoisting compartment was lined on 4 sides with 1 inch boards. A cross-section of the shaft is shown on Plate VIII. The cost of timbering the shaft was $1.35 per foot, with sawn timbers at $1.70 per M. The lagging was started at the corners and driven down between the ring timbers and lagging of last set, and were always kept driven ahead, except when working in rock. A sort of spring-pole method was used overhead in the levels, and sides also in very soft ground. The levels were 5 by 6 feet over all, and timbered every 4$\frac{1}{2}$ feet with 6 to 8 inch round timbers. The cost of timbering in the levels was about 60 cents per foot. Oak timbers and lumber were used throughout.

The vein at this place lay in an E. & W.
direction and dipped south at about 80° to 85°. The shaft was started south of the vein with the idea of cutting it at about 100 feet. At 90 feet the edge of the vein material was reached, - clay and spar mixed. A crosscut showed this to be about 20 feet wide. The north wall seemed to be blue clay of quartzitic origin, - the south wall was not reached. East and West drifts were run on the spar, which narrowed and widened and changed its course as shown in Plate VI. Everywhere was found clay of various colors and consistencies impregnated with spar; with veins of spar running through the clay. Some of the spar was of the very best grade and contained quite a little galena. In places the spar lay flat, in others it stood on edge; in one place lump, in another gravel. This showed that movement had taken place after the formation of the spar; - some gravel spar seemed to have been washed into place in layers. In places we cut into what we think was the north wall.

This drifting was rather discouraging, as only about 100 tons of spar was found; so it was proposed to sink to the 150 foot level and try again. Up to this time the shaft had been practically dry, but increased depth would bring water; so a boiler, hoist and pump were secured. The company made a mistake here in not buying
large enough machinery for deeper mining. They borrowed a 16 horsepower vertical boiler, an 8 horsepower engine, and bought a duplex pump of the boiler feed type, with a 2 inch discharge. These would barely do for a 100 foot shaft, but were no good for deeper work, and gave no end of trouble. Plate VII gives the arrangement of the machinery that was first installed.

As a large percentage of the spar was dirty a washer was built. Being unfamiliar with washers, we yielded to advice and installed a sluice washer, the design of which is shown on Plate II. The spar left the washer clean, but the process was slow and costly. The slope of the ground was not sufficient to give the trough enough fall, and the trough was found to be too wide, shovel-width being better. The bin at the upper end held 10 or 15 tons of spar, which was soaked and washed down the sluice. The sluice was 12 inches wide, with 6 inch side boards; and a screen at the end unwatered the coarser gravel, while the sand passed through into a sand-box. The shaft was now 165 feet deep. Ninety-six days had been required to sink the 72 feet at an average cost of about $26.00 per foot.

The high cost of this work showed what a mistake had been made, and the company now agreed to purchase better equipment for further work. Care was used in
the selection, and a new plant was installed consisting of an 8 x 7 inch single cylinder Sampson, cone-friction, geared hoist, and a 40 horsepower Wangler, circular fire-

box, portable boiler. These proved to be the best hoist and boiler of their size in the district. The company could not see the need of a new pump, the most
important of all, so that source of expense and annoyance continued. Plate VIII shows the arrangement of the machinery and tank, also the pump that was finally purchased. A larger water tank was needed for the new boiler, and for a reserve, so one of 2000 gallons capacity was built.

Specimens of fluorite: (a) showing slickensiding, (b) spar and zinc, (c) flint cemented by spar.

The 150 foot level was now started with the expectation of finding a good body of spar. All data so far obtained indicated that the vein lay to the south. This level proved, however, to be similar to the one above, except that the south crosscut uncovered
what seemed to be solid limestone. From the contact a small stream of water flowed continuously. Spar was found of the very best grade, but only in small quantities. A cut to the north showed only sandy clay for some distance and was abandoned. Another cut to the south farther along gave clay and flint so soft that it filled up the level faster than it could be shovelled out, and had to be bulkheaded. A plan of this level is shown on Plate IX. To facilitate work in the main drift and cross-cuts, the author designed a cheap but efficient turntable. An article describing this turntable and drawings appeared in the Engineering and Mining Journal for August 13, 1910, Vol. 90, No. 7, page 305. See Plate X.

Determined to sink farther, and being now convinced of the need of a new pump, the company consented to its purchase. A #5 Cameron vertical, plunger, sinker pump was installed, being considered the best for the purpose. Another 31 feet was sunk this time making the shaft 196 feet deep - the deepest in the vicinity. The average cost was $12.40 per foot, which give an idea of the loss caused by the old pump, although other conditions helped to lower the cost.

At about 180 feet drifts were started north and south. The south drift ran into soft clay and flint,
similar to that found in the last crosscut at the 150 foot level, and had to be bulkheaded. The north cut developed only blue quartzite mud and small boulders and was stopped. At 165 feet, where spar was noted in sinking, another cut was made north and some gravel spar was found and more water. Plate XI shows the plan of these two levels.

The author believed, and still believes, that a parallel fault on the south would develop spar, but the company refused to do any more exploration work on the south side. They had been urged for the past 5 months to start another shaft, where the spar had been reported near the western boundary, as was mentioned above; so it was finally decided to sink a new shaft, and abandon the old one. A contract was let at $5.50 per foot, spar was struck within 30 feet, and levels at 70 and 100 feet are now producing gravel and lump spar. Already 200 tons have been shipped and 400 tons are piled on the dump. From experiments made by the author with a sluice and log washer the relative cost was shown to be 55 cents for the logs as against over $1 per ton for the sluice, on very dirty stuff. A set of logs and an 8 horse power engine was then installed but this cannot wash fast enough. The production is figured at 20 tons per day, at a cost of about $1.80 at the mine and $3.65 loaded on the
cars at Mexico. With spar at $6.50 per ton this gives a daily profit of about $57.00.

Fuel tests at the old shaft showed that 33.75 tons of coal and 86 cords of wood lasted 245 shifts of 9 hours each, or about 90.5 cents per shift. Another time 30.4 tons of coal and 11.75 cords of wood lasted 115 shifts, or about 89.8 cents per shift. Tests on the flow of water in the mine and the rate of pumping, gave 5.3 gallons per minute, rising 19 feet in the shaft in 15 hours; and required 84 minutes pumping which gave 63.4 gallons per minute as the pump capacity. As a check, the discharge was measured, which filled the 2062 gallon tank in 33 minutes, or 62.5 gallons per minute.

CONCLUSION.

On Plate XII the author has given a sketch of the probable conditions, which would explain the absence of spar in paying quantities at the first shaft, and the presence of spar at the new shaft. Parallel veins are known to exist, and the data at hand points to this explanation. St. Louis limestone was found on the south and this wall possibly separated the two veins.

The thickness of the Mississippian rocks, through which the faults probably extend, would indicate a long life to many of the mines. The large number of
faults and veins should give to the country other mines in the future. The advanced price of spar will increase the mining operations, and with more modern methods, this district should gain in importance.
BIBLIOGRAPHY.


Burchard, Ernest F. - Production of Fluorspar and Cryolite in 1908, 1909.

____________ Production of Fluorspar and Cryolite in 1909, 1911.


Ries, Heinrich - Economic Geology of the United States 1905.

Ulrich, F. O. and W. S. Tangier Smith - The Lead, Zinc, and Fluorspar Deposits of Western Kentucky; - Prof. Paper U. S. Geol. Survey No. 36, 1907.
Ky. - Ill. Fluorite Dist., area included by........ 4
Kentucky mine, description of........................ 12
Klondike mine, description of........................ 10
Level, 90 foot, description of........................ 27
  150 " " " ........................................ 30
  165 " " " ........................................ 32
  180 " " " ........................................ 31
Machinery, first outfit of............................. 28
  second " " ........................................ 29
Mansfield sandstone, occurrence of.................. 18
Memphis mine, description of........................ 10
Minerals, occurrence of other, in vein.............. 18
Mining, general methods and costs................... 7
Mississippian rocks, occurrence of.................. 14
Nickel, occurrence of................................ 18
Ohara limestone, description of...................... 15
Ore deposits, occurrence of, genesis of............. 21
Parish mine, description of.......................... 12
Pennsylvanian rocks, occurrence of.................. 15
Pogue mine, description of............................ 12
Princeton rocks, occurrence of....................... 15
Production, statistics on................................
  of new shaft of Am. F. M. Co......................... 32
Rosiclare sandstone, description of.................. 15
St. Louis limestone, description of.................. 14
St. Genevieve group, description of.................. 15
Shaft, cost of sinking................................. 24, 28, 31, 32
Sink holes, occurrence of.............................. 15
Sphalerite, occurrence of............................. 18
Stratigraphy........................................... 14
Tabb group, mines of the.............................. 11
  mine, description of................................ 11
Tests, on fuel......................................... 33
  pumping............................................. 33
Timbering, level........................................
  shaft.............................................. 26
Topography............................................. 5
INDEX.

Am. Fluorspar M. Co's. mine, location of................. 23
Asbridge mine, description of.................................. 11
Banded structure, occurrence of.................................. 18
Birdsville formation, description of.......................... 15
Carboniferous rocks, occurrence of.............................. 14
Chester Group, description of.................................... 16
Cobalt, occurrence of............................................. 18
Columbia mine, description of.................................... 10
Contracts, hauling................................................... 25
sinking............................................................... 24, 32
Cypress sandstone, description of............................... 15
Depth of mines........................................................ 7
Development, history of............................................. 6
Devonian rocks, occurrence of................................... 14
Dikes, occurrence of............................................... 17
composition of........................................................ 23
Districts, mining..................................................... 1
Enrichment, secondary............................................... 21
Faulting............................................................... 16
Faults, character and number of.................................. 17
Fluorite, description of.......................................... 19
Fluorspar, grades of................................................ 9
production for 1909................................................. 2
selling prices of.................................................... 2, 9
uses of........................................................................ 3
Formations, table of................................................. 14
Fredonia oolite, description of................................... 15
Galena, occurrence of................................................. 18
Geography............................................................... 4
Geology................................................................. 14
Hodge mine, description of........................................ 13
Illinois, deposits in................................................ 4
Jackson, Andrew, explored by........................................ 6
Jim mine, description of............................................ 11
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation by rail</td>
<td>9</td>
</tr>
<tr>
<td>&quot; road</td>
<td>8</td>
</tr>
<tr>
<td>Turntable</td>
<td>31</td>
</tr>
<tr>
<td>Veins, description of</td>
<td>17</td>
</tr>
<tr>
<td>Water, excess of</td>
<td>13</td>
</tr>
<tr>
<td>level</td>
<td>21</td>
</tr>
<tr>
<td>Washers, kinds of</td>
<td>8</td>
</tr>
<tr>
<td>Washing, methods of</td>
<td>28</td>
</tr>
<tr>
<td>costs of</td>
<td>32</td>
</tr>
<tr>
<td>Weathering</td>
<td>21</td>
</tr>
<tr>
<td>Wheatcroft mine, description of</td>
<td>11</td>
</tr>
<tr>
<td>Wheeler mine, description of</td>
<td>11</td>
</tr>
<tr>
<td>Yandell mine, description of</td>
<td>12</td>
</tr>
</tbody>
</table>
Map of 150-foot Level

Scale 1" = 8 ft.
PLAN

TURNTABLE FOR WOODEN TRACK

Designed by W.C. Richards.

Scale 1" = 1Ft.

SECTION
Map of 165-ft Level.

Map of 180-ft Level.

Scale 1" = 8ft.
Sketch of Probable Conditions
at the mine of the
American Fluorspar Mining Company

BIRDSVILLE FORMATION

FLUORITE
CLAY AND SCATTERED FLUORITE
Old Shaft

LIMESTONE
Probable parallel/vein of fluorite

CYPRESS SANDSTONE

ST. LOUIS LIMESTONE

Fault S 57° 30' E.

Property Line
Kentucky Shaft
New Shaft
Court R.O.D.