

THE HISTORY OF SALTPETRE MINING IN MAMMOTH CAVE, KENTUCKY*

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Part IV SALTPETRE MINING AND RECOVERY PROCEDURES

FOREWORD

Evidence indicates that saltpetre was mined at Mammoth Cave a number of years before the start of the War of 1812. However, in order to determine that an increased production caused by war was possible and feasible, it was necessary to analyze the cave earth from a number of widely scattered locations, for the percentage of saltpetre content; determine whether or not there was a sufficient amount of nitrate-bearing earth to warrant an expanded operation; and, to investigate a number of other factors such as availability of the necessary man power, conversion alkali, and water supply. Since it is impossible to know the extent to which these problems were investigated, what suggestions were offered, and which or how many were discarded, any attempt to reconstruct the activity must be based on the interpretation of the presently remaining equipment and any authentic records which are available. In light of a small number of first-hand reports and the condition, type, construction, and distribution of these existing artifacts, which were so carefully studied and beautifully described by Thor Borresen and Ralston B. Lattimore,¹ it is possible to reconstruct, with some reasonable degree of accuracy, the specific mining and recovery operations as they were conducted at Mammoth Cave.

Most of the presently available and alleged historical accounts of saltpetre mining at Mammoth Cave have been based on meager fragments of semi-confirmed information mingled with legendary interpretation by apparently well-meaning, self-styled authorities who have advanced profound conclusions. However, most of such reports have been based almost entirely on secondary references most of which were never prepared or appeared in print until many years after the termination of the recovery operation.

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There is a considerable amount of material, closely contemporary with the Mammoth Cave saltpetre mining activities, which has come to the attention of the present author. All this material presents evidence of originality and authenticity. Apparently substantially all of which has been overlooked by or unknown to the earlier writers and bibliographers of the cave. Practically no reference to any of this material or the information contained therein appears to have been used by any historians or other writers with whom the present author is acquainted.

In addition to the above, two excellent type-script reports, which were prepared after a careful and thorough study of the remaining artifacts, have been made available. These reports contain drawings of a meticulous reconstruction of the leaching vats. They give sizes, dimensions, methods of construction, kinds of wood used, and suggest possible manners in which the equipment might have been used.¹

PREPARATIONS FOR MINING OPERATIONS

LEACH-WATER SUPPLY

It is impossible to conduct a cave-earth leaching operation for saltpetre without a plentiful supply of fresh water which is reasonably conveniently available. Many different expedients were used by the saltpetre miners either to get the petre-dirt to the leach-water or to get the leach-water to the petre-dirt. Sometimes as in Meredith Cave, in Tennessee, bags of cave-earth were saddled across the backs of horses or mules which small boys rode from the mining area to the leach vats which were located adjacent a stream some distance from the cave entrance.¹ Sometimes as in Repass Cave, in Virginia, ceiling drip water was collected in troughs made from hollowed logs. Sometimes as in Teamers Cave, in Kentucky, a wooden pipe line was laid to conduct water from inner recesses of the cave. Sometimes as in Buchanan Cave, in Virginia, an underground stream was sufficiently close to the petre-dirt deposits that the water was carried in buckets or piggins.

The operation at Mammoth Cave was one of the largest installations of this type in the country. Therefore, because of its size, it presented some rather unique problems in water supply. While there were some small springs, inside the cave, within a reasonable distance from the petre-beds, the volume of water they provided was much too small. The rivers in the bottom of the cave were too far away and only accessible through tortuous passages. These factors meant that an outside source had to be located and special provision made to get the water to the leaching vats. Apparently it had been decided to locate the leach-vats in the cave, close to the petre-dirt beds, for at least two reasons;

one, it was easier to provide water by gravity flow rather than to transport the great tonnage of cave earth it was planned to handle; and two, it was known that if the leached earth were left in the cave it would rejuvenate itself and in about three to five years it could again be leached for additional saltpetre.

A great number of so-called travelogs were written, after 1845, by many persons of diverse interests who had come from widely separated parts of the globe, traveled in various sections of the North American continent and visited this *Wonder of the World*, the Mammoth Cave. It appears that not many such reports were left by native American citizens. Some of these writers recalled and reported the presence of a stream of water which flowed into the cave. Such a stream is evident in the picture of the "Entrance To Mammoth Cave," published in Part I of this Article (January, 1967 issue of the *Quarterly*, p. 8). A few of these writers made a casual mention of ruins of furnaces, which are also clearly seen in the same picture, along the path which was followed to the entrance of the cave, and of a wooden pipe-line which led into the cave. They apparently either had no appreciation of or interest in, or the guides never explained, the relation between the stream, the pipe line and the saltpetre works.

Since the travelog type of report generally does not give much information other than hearsay or average tourist guide type of second-hand reports it is necessary to investigate statements made by men who had first-hand knowledge of saltpetre mining at Mammoth Cave.

One of these men was Ebenezer Miriam who published an article about Mammoth Cave, in the *New York Municipal Gazette*.² According to *Appleton's Cyclopaedia*,³ Ebenezer Miriam was a meteorologist, and apparently had a number of other skills, born in Concord, Massachusetts, on June 20, 1794, and died in Brooklyn, New York, March 19, 1864. He moved to Kentucky in early manhood, where "... he engaged in the manufacture of saltpetre and other mineral products of the Mammoth Cave." While he reports that he made his "... first visit to Mammoth Cave in 1813," he further states in his article which was published in 1844, "I have not been at the Cave since the manufacture of Saltpetre was suspended there, near the close of the war. ... My Knowledge of the Cave is extensive, and from personal observation made at various times, although more than a quarter of a century ago, yet notwithstanding the lapse of time, my recollection of this wondrous place is quite distinct."

With regard to the water supply for the leaching operations, Miriam states, "At the mouth of the cave there is water dripping from above. ... Near the mouth of the Cave is a pit of water, of some fifty or sixty feet deep. ..." While this statement does not give any definite

idea of the volume of water in the drip it evidently was sufficient for the processing needs. Miriam further states, "Wooden conduits (logs through which an axial hole has been augered) were used for conveying water from the mouth of the Cave to the Hoppers, to lixiviate the earth, and the same mode of conveyance was resorted to, to convey the nitrate solution from the Hoppers to the mouth of the Cave, from whence it was raised by pumps, into the iron pans in which crystallization was affected."

While Miriam's statements are acceptable at face value, there is an even earlier source which provides additional confirmation of the water supply situation and of activities at this recovery operation. Records, collected from a number of sources, and which have been excellently preserved and carefully catalogued, in the Eleutherian Mills Historical Library at Wilmington, Delaware, constitute a prime source of information. Some of these records date back to the early part of 1808, and are concerned with transactions between the du Pont gunpowder manufacture and saltpetre merchants, collectors, and shippers in nearly every saltpetre producing region of the United States.

Sometime prior to June 11, 1811, an unknown artist^m prepared and sent to E. L. du Pont "AN EYE-DRAUGHT of the MAMMOTH CAVE in Warren County, [Ky]." (See page 231.) On this date Thomas Lawⁿ wrote du Pont and stated, "I mentioned to Mr. [Albert] Gallatin [Secretary of the Treasury in Jefferson's cabinet] that you had the plan or drawing of a cave 37 miles long in which there was saltpetre etc. He is very solicitous of seeing it, if there is no impropriety in the request you will oblige me with a copy to be sent by some Gentleman coming here."⁴ While this map is not drawn to a very critical scale, there are identifiable locations which can be co-related to corresponding points in one of the earliest known and reasonably accurate maps prepared by Edmund F. Lee⁵ from an instrument survey he had made and published in 1835.⁶ This map together with a number of informative notes which are written adjacent the delineation of the cave passages, shed a considerable light on, and provide much information relative to early saltpetre mining in Mammoth Cave.

The artist in his notes states that there is, "A large spring falling into the mouth of the cave — 50 feet high from which water can be conveyed, in pipes to any part of it." In addition he states that, "The principal cave is from 50 to 80 feet wide, and about 30 feet high generally. At the Big room (to which it is contemplated to convey the water and erect leeches) [*sic*] it is 100 feet wide and 40 to 80 feet high. It has been explored about 7 miles from the termination of the narrows. The clay, impregnated with nitre, has been found to be generally about 5 feet thick extending quite across the cave. Under the

clay is a vast body of fine dry sand, the depth of which has never been ascertained. The clay in the principal cave produces 6 lbs. of Salt Petre to every bushel, the sand produces one to the bushel."

From these statements it seems evident that the large installation of equipment, as indicated by the extent of the artifacts which still remain in the cave, had not been contemplated at the time this map was drawn and the notes written. It also seems evident that the identification of the existence and location of leach vats, in a passage adjacent the entrance, and the reported amount of saltpetre in the cave earth are clear evidence that leaching operations had been in progress for some time. The closest date it appears possible to establish for this map is June 11, 1811. Many persons have made the statement that Valentine Simmons sold the cave property for \$116.67. However, recent investigations indicate that such probably was not the case. Harold Meloy^o expresses the following thoughts on this matter. "I am quite sure that Simmons received considerable more than that when he sold the cave more than four years before, and that \$116.67 was only the balance due, principal and interest, which was paid him in 1812. Also, that from 1808 or before, Simmons did not own Mammoth Cave; when the title was finally cleaned up, he gave the deed for the legal title, but that ownership was actually in others." This seems like a logical explanation of such a small sum of money even though future studies may differ.

There is yet another confirmatory source of information about the early mining of saltpetre in Mammoth Cave. On page 84, of Volume 2, of the *Daniel Drake Papers in the Draper Collection*,^p Series O of the Draper Manuscripts,⁶ is a map entitled *Mammoth Cave in Warren County on the Banks of the Green River, Ken.* (See pg. 233.) While this map is undated it does clearly show and identify two separate sets of "hoppers for leaching salt petre." Another map on page 80 of this same volume is also undated. This bears a marginal note which reads, "Mrs. [John P.] Campbell conjectures this is a cave near the Green River in which a mummy was found."

These two maps appear substantially contemporary. Dr. Daniel Drake who made a considerable study of the Aborigines of the Ohio Valley left many papers of his findings which seem to center about the middle of the first decade of the 1800's. It seems reasonable to assign a date of about 1806 to them. In light of the apparent free-hand draftsmanship they must have been drawn from memory and without the use or benefit of any instruments. It also appears that there is a possibility the Drake maps pre-date the du Pont map, even though the leach-vats are shown at different locations.

While Miriam states "The cave was extensively mined for Saltpetre

from 1810 to 1814," this does not preclude earlier production. Data from the 1810 United States Census Reports, which was the first time an attempt was made to give information relative industrial and mineral production in the United States, indicates that Warren County, Kentucky, in which Mammoth Cave was located, reported a production of 22,850 pounds of saltpetre. The two operating powder mills in the county reported a production of only 400 pounds of gunpowder. Such would require only about 300 pounds of saltpetre. Evidently most of the saltpetre produced was shipped to other parts of the country to be manufactured into gunpowder.

All of the primary sources of information presently known appear to be in agreement on two points: (1) that active production of saltpetre was established and in operation well before 1810; and, (2) that the necessary water in plentiful supply for the leaching operation was available at the mouth of the cave, even though at times it might have to be supplemented with water from some of the various known springs within the cave.

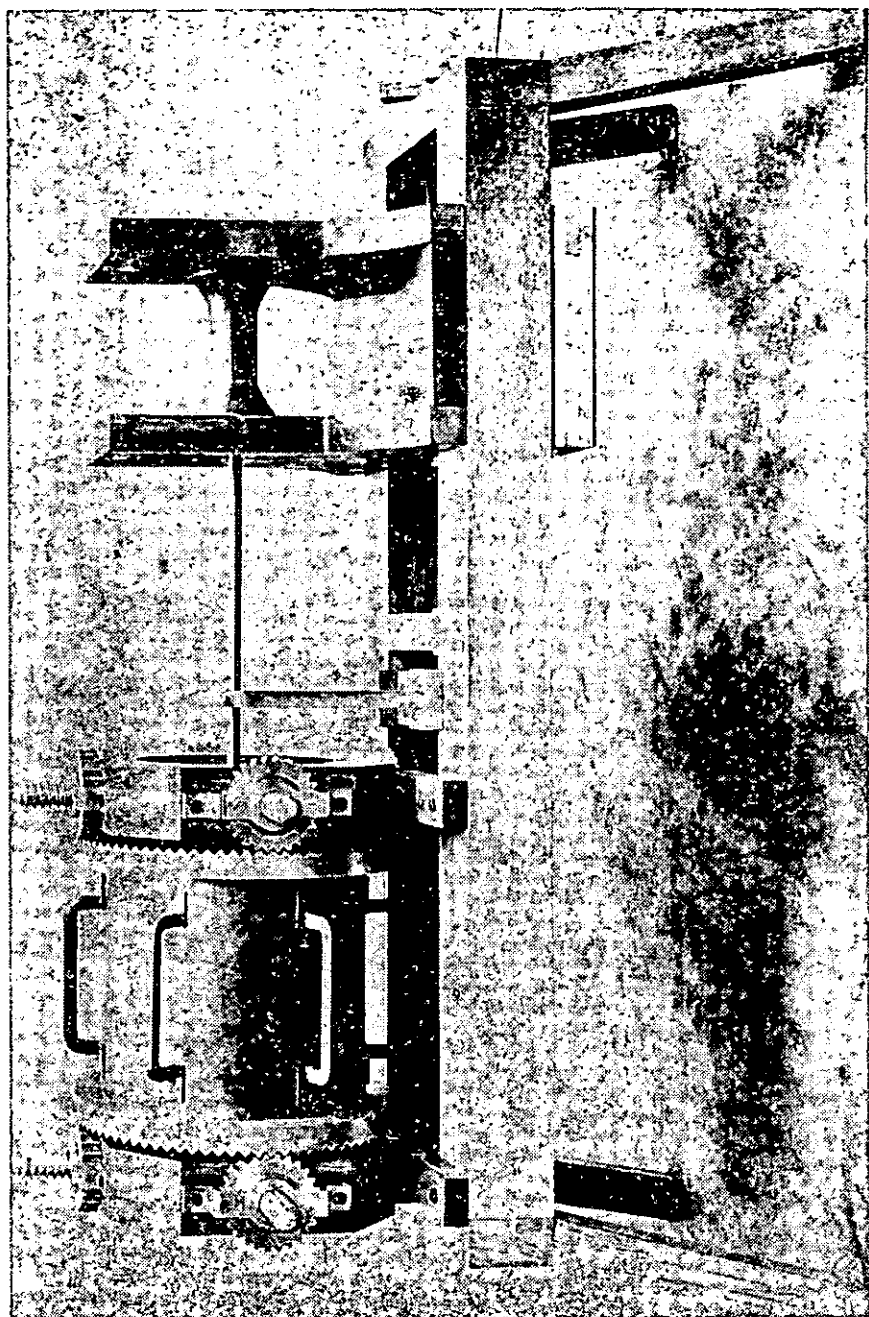
Even with the sufficiency and availability of the water supply established, there still remained the problem of its transportation to the leach-vats and its return to the mouth of the cave and thence to the boiling kettles. The manner in which this problem was solved will now be considered.

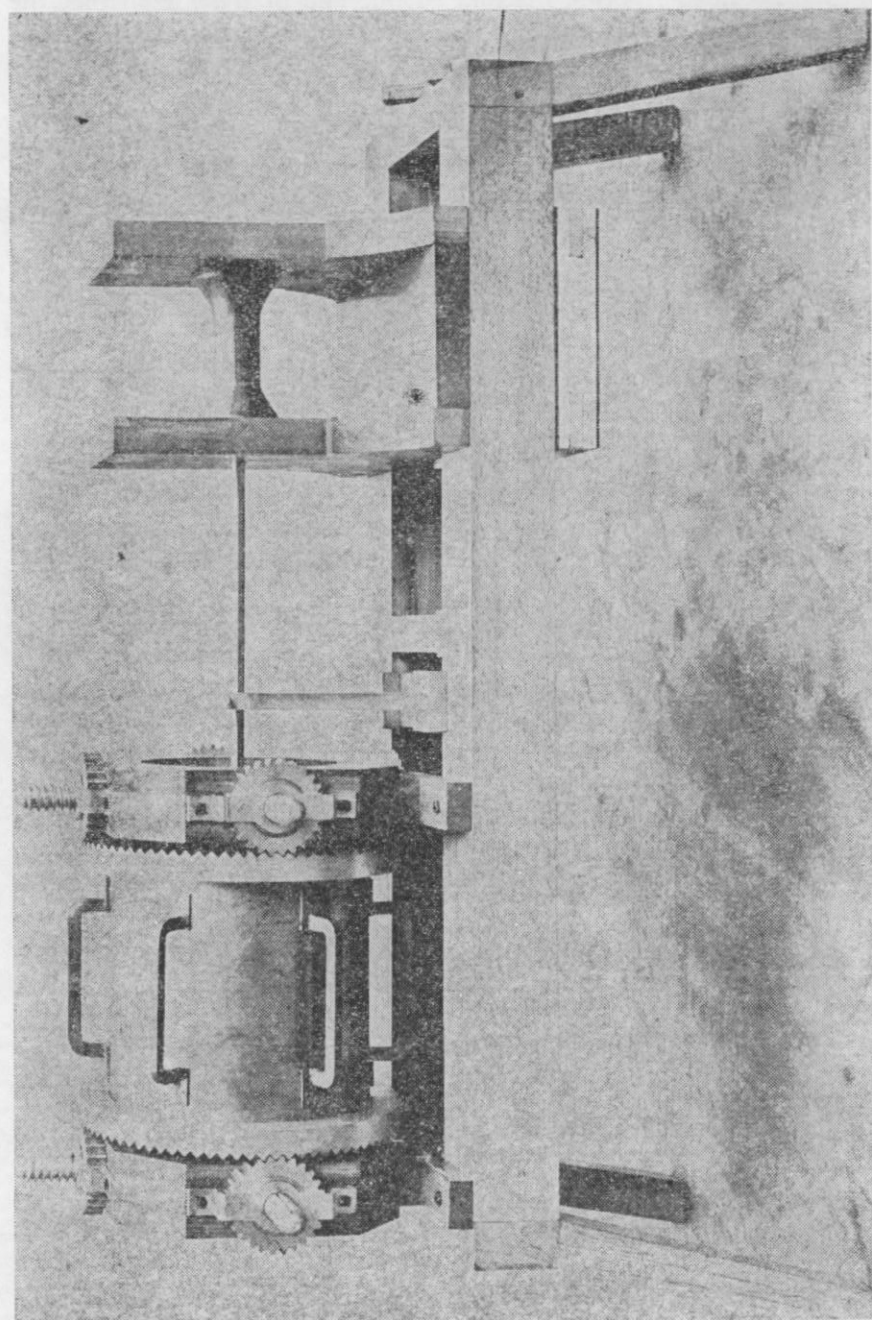
WATER CONDUITS

Since metal pipe was not obtainable, the developers and operators of the mining operation, like all other pioneers, utilized available material. There was an abundance of straight-grained trees from which the necessary water pipes were made. To take a log 6 to 9 inches in diameter and by means of an auger bore a hole about three inches in diameter, from end to end along its longitudinal axis, was no small accomplishment. Some of these water pipes which still remain in Mammoth Cave are in excess of 26 feet in length. Leonardo da Vinci (1452-1519) has been given credit for inventing the machine used to bore holes through the length of logs.⁷ A photograph of a working model of this machine based on Leonardo's original sketches is shown on opposite page.

The use of the log boring machine will be evident from the following step-by-step description of the procedure followed in the operation.

1. Select a clear straight-grained log, free of knots and limbs, and about 6 to 9 inches in diameter throughout its length;
2. Mount the log in a level position on a support sufficiently strong and rigid that it cannot jump, roll, or fall during the boring operation.





3. Locate the boring machine at one end of the log so that the lead-screw of the auger is accurately centered along the longitudinal axis of the log and held so it cannot wander or chatter during use;
4. Rotate the auger and feed it ahead as it cuts its way into the log;
5. Withdraw the auger bit periodically, so the cut chips can be removed from the working face and to keep the finished portion of the bore clear;
6. Inspect the condition and sharpness of the auger bit and if necessary use a block of fine-grained sandstone to whet the cutting edges; and,
7. Continue this operation until the tool appears at the far end of the log.

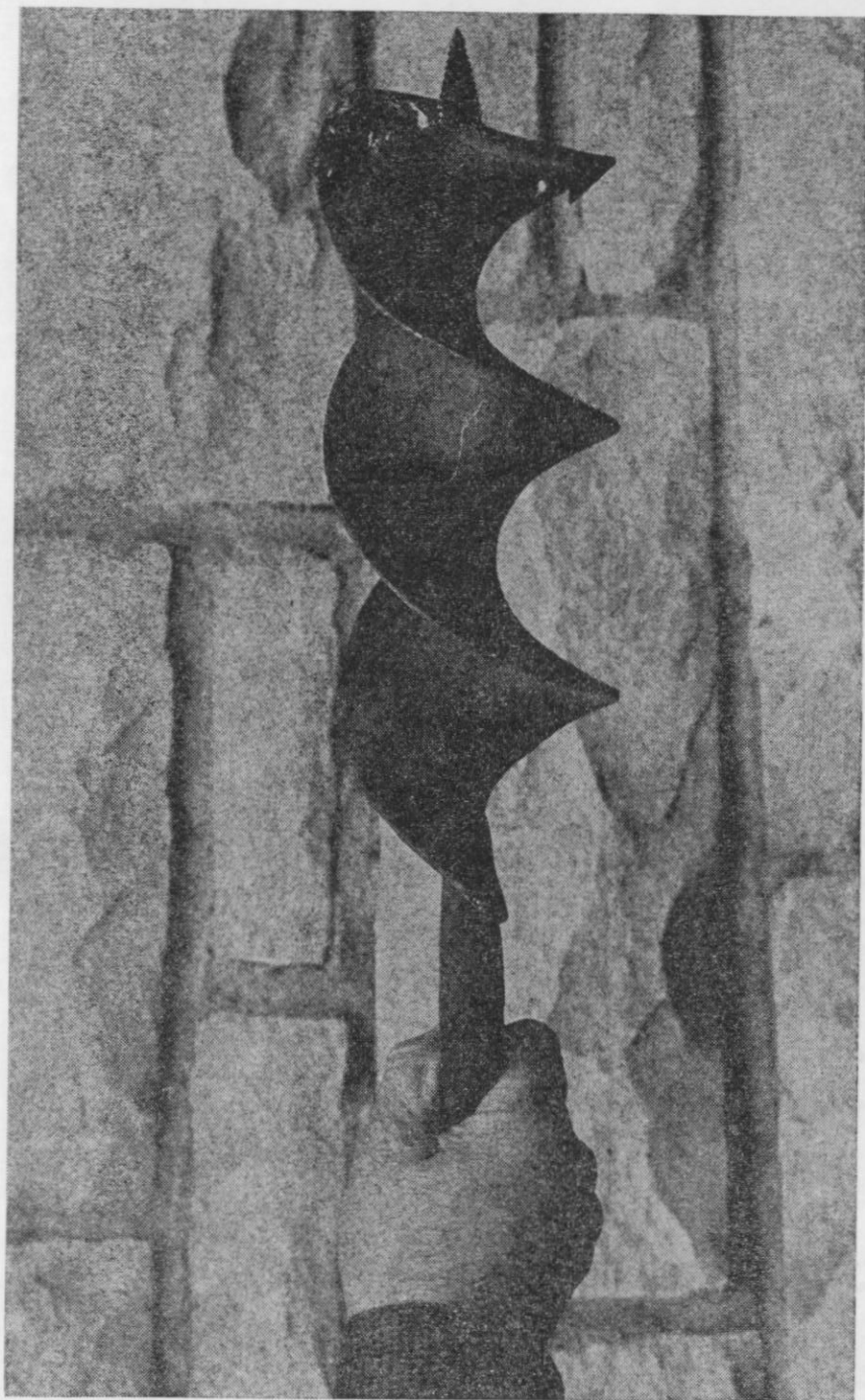
If occasionally a hidden knot or hard portion within the log caused the tool to stray from the central alignment and break through the side of the log the boring operation, of course, was stopped. However, this did not necessarily mean that the entire log was discarded, a portion of the bored section might be salvaged and thus provide a shorter section of conduit.

In light of the process of boring a log to make a conduit a number of significant features in Leonardo's machine become evident. It will be noticed that the log holder has an ingenious clutching arrangement. Rotation of the outer or drum-like portion will cause the ring-gears which surround the drum to rotate the equally spaced pinion gears. These in turn will advance the screw-threaded rod which extends through each of the pinions and thus carry the holding or gripping log on the inner end of each rod toward the central axis of the drum. Thus the log would be automatically positioned and locked in a centered position.

An auxiliary support, not illustrated, is adjusted to the log level and in a firmly retained position. The boring auger bar, which is carried by a guide close to the end of the log and on the framework at the right-hand end of the tool support, is illustrated as a bar in the face of the upright and may be of any desired length. The spoked hand-wheel, fastened to a screw mounted within the lower frame, is rotated to advance the cutting blade on the boring bar as it is turned by means of a crank on the bar. The spool-like element between the uprights is a clutch which will firmly grip the boring bar as it is advanced but will release its grip when the uprights are returned for another bite on the boring bar.

The picture on opposite page shows one form of auger which was used to bore wooden water pipes. The original of this tool is in the possession of John Lair, Renfro Valley, Kentucky.



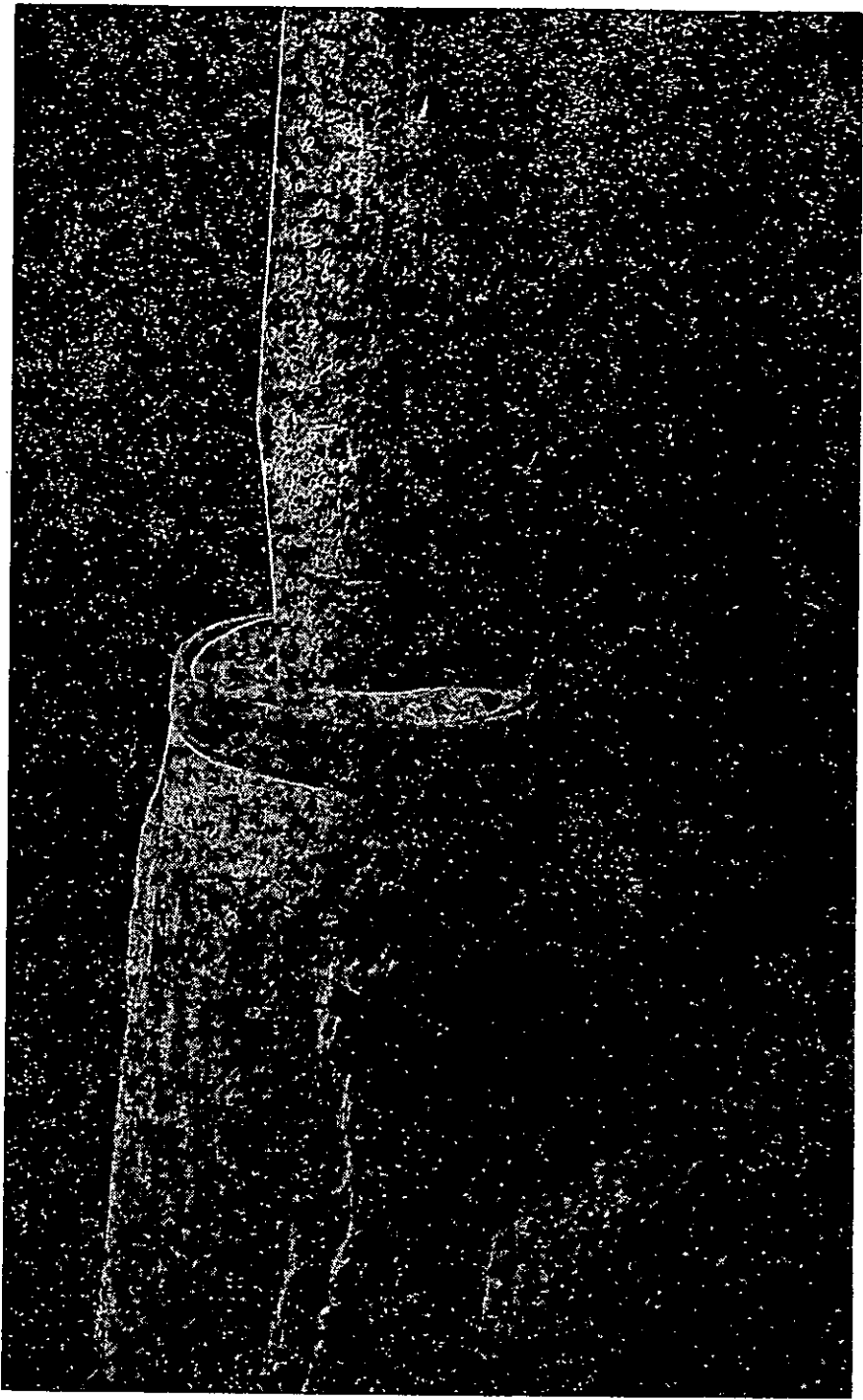


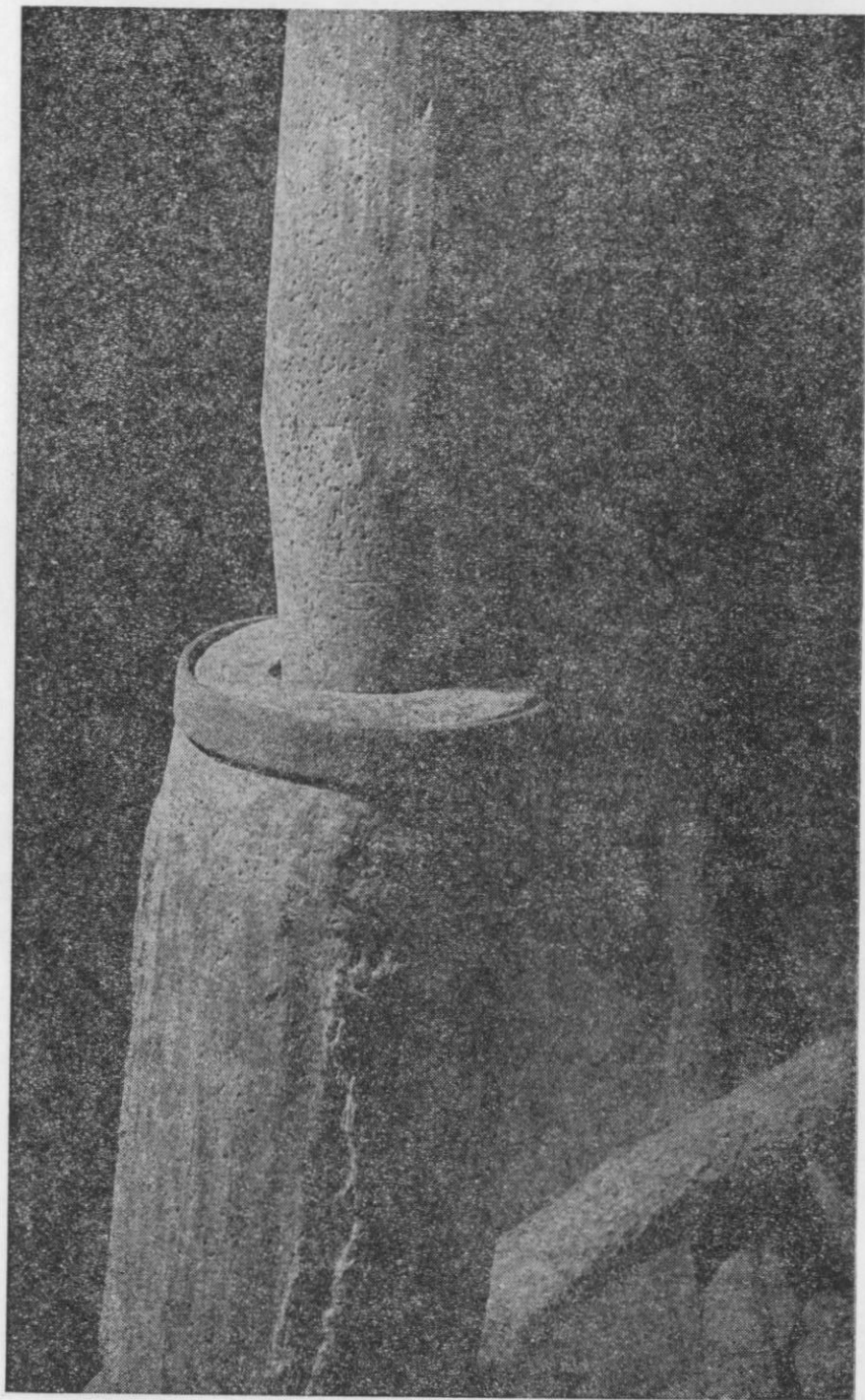
Even after the logs had been bored they were still not ready to use. It was necessary to provide a means to join the conduits end-to-end and thus form a continuous pipe line of the needed length. To provide the joint means, one end of the bored conduit was beveled like the wood in a pencil point and the opposite end of the conduit was beveled in the opposite direction or from the bore outwardly. Thus, two inter-fitting cones were formed which when driven together formed a water-tight spigot and socket type of joint, as shown in the picture on page 239. The outer log adjacent the joint carried a ring of wrought iron which had been heat-fitted to prevent any splitting which might result from driving the joint too tight or by water causing the wood to swell.

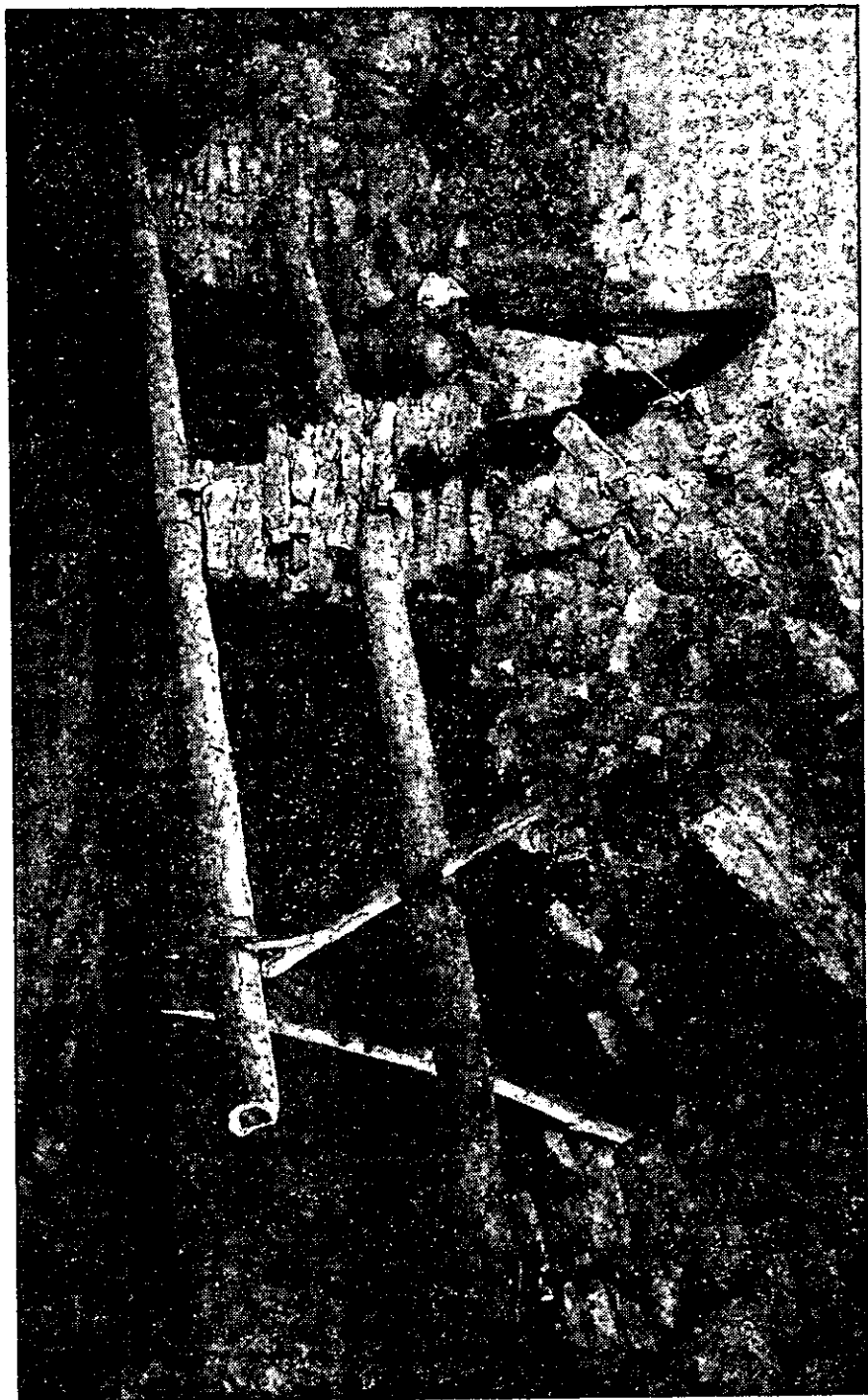
The tool used to form these interfitting bevels on the ends of the log conduits is unique and of remarkable design. One of these tools is to be found in the Historical Museum in Virginia City, Montana. This tool is very like an old-time pencil sharpener which had a cutting blade mounted on the inner face of the cone-shaped holder and set at such an angle that it would cut a tapered point as it was rotated about the end of the pencil. This log-tapering tool, in addition to an inner angularly mounted cutter blade or edge has an outer cutter mounted at the same angle on the common support. Thus, as the tool was rotated about the end of the log, one or the other of the blades was operative to cut either an inner sloped or an outer sloped cone on the end of the log. The cutter blades being mounted at the same angle insured a close, tapered fit between the log ends when assembled. Thor Borresen, in one of his drawings, as shown on page 239, illustrates a typical form of bored and tapered log and gives exemplary dimensions.

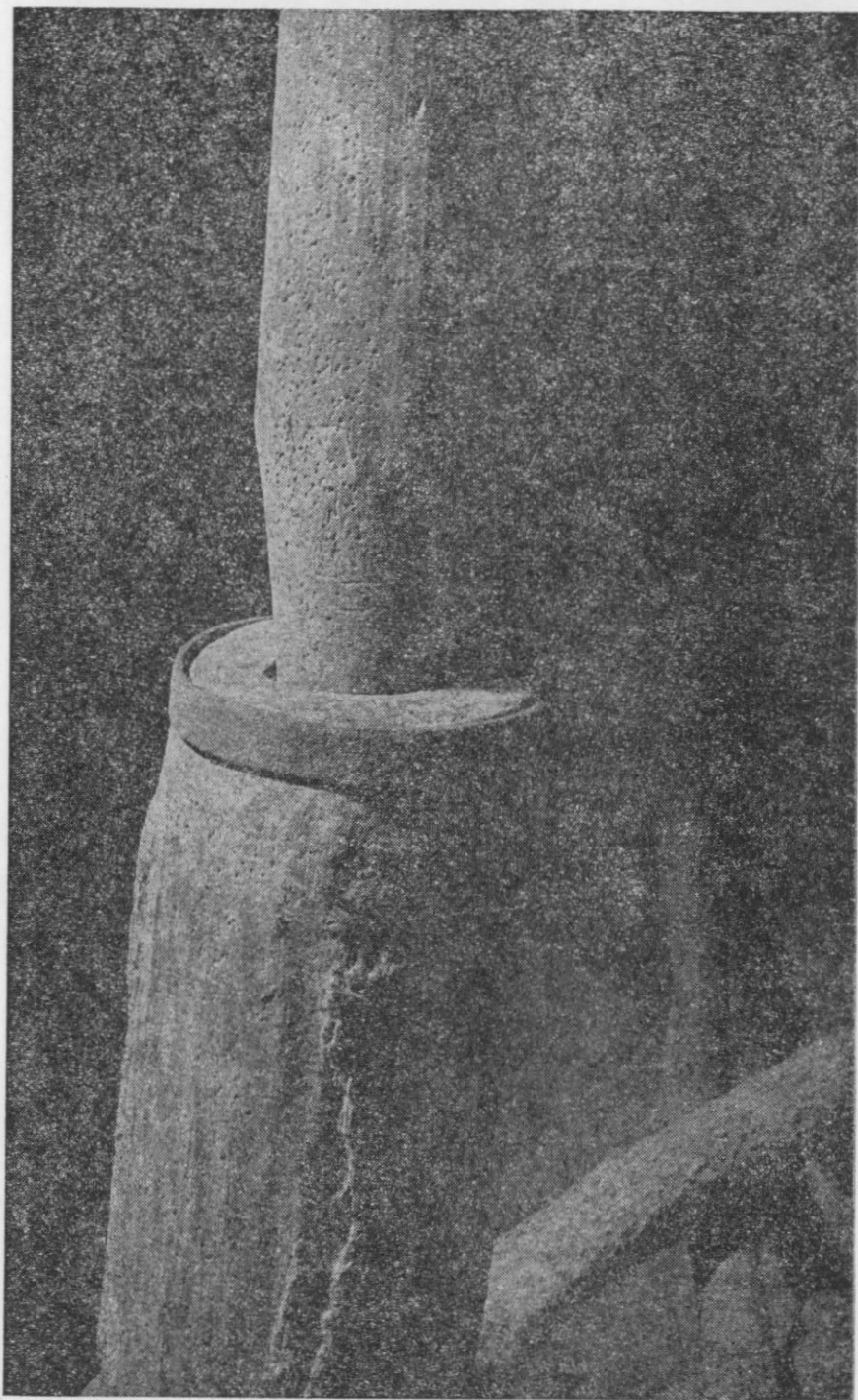
Two such pipe lines, one for fresh water and the other for the leach-water, were laid from the cave entrance to the leaching vats. Since the slope of the cave entrance portal was inward and downward the fresh water flowed by gravity to the points of use. In general, this in-flow or fresh water line was laid along the floor of the cave. It was elevated and supported on stone pilasters only to cross pits or other floor depressions or to feed a pipe line which was laid adjacent the tops of the different sets of leaching vats. The picture on page 240 illustrates how such a pipe line to supply water to the leaching vats was installed.

Since the flow of the fresh water to the leaching vats was all down-grade the return of the leach-water to the boiling furnaces outside the cave involved problems which required some rather unique methods of solution. However, the discussion of manner in which the leach-water was handled will be considered after the leaching vats and their use have been described.







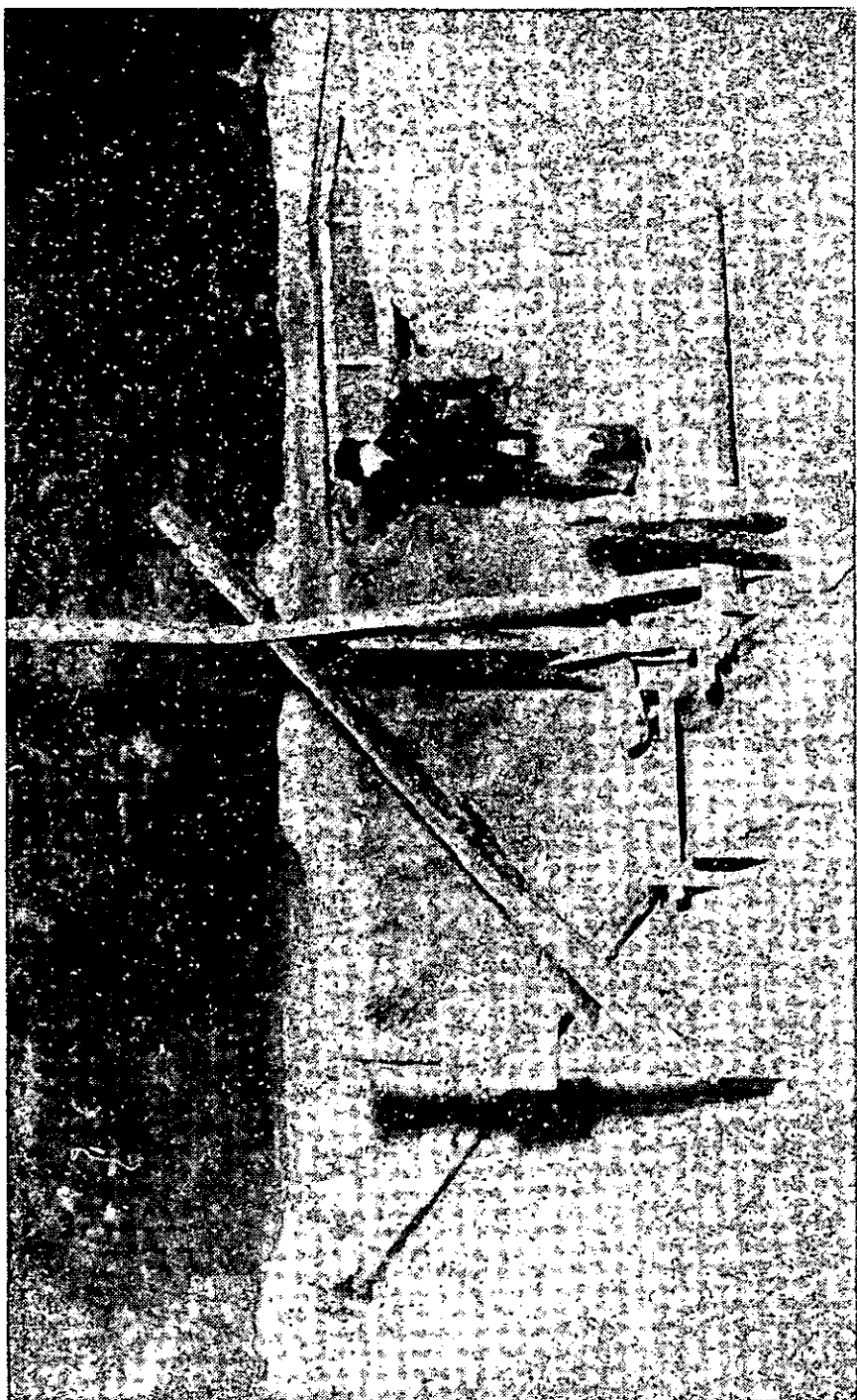


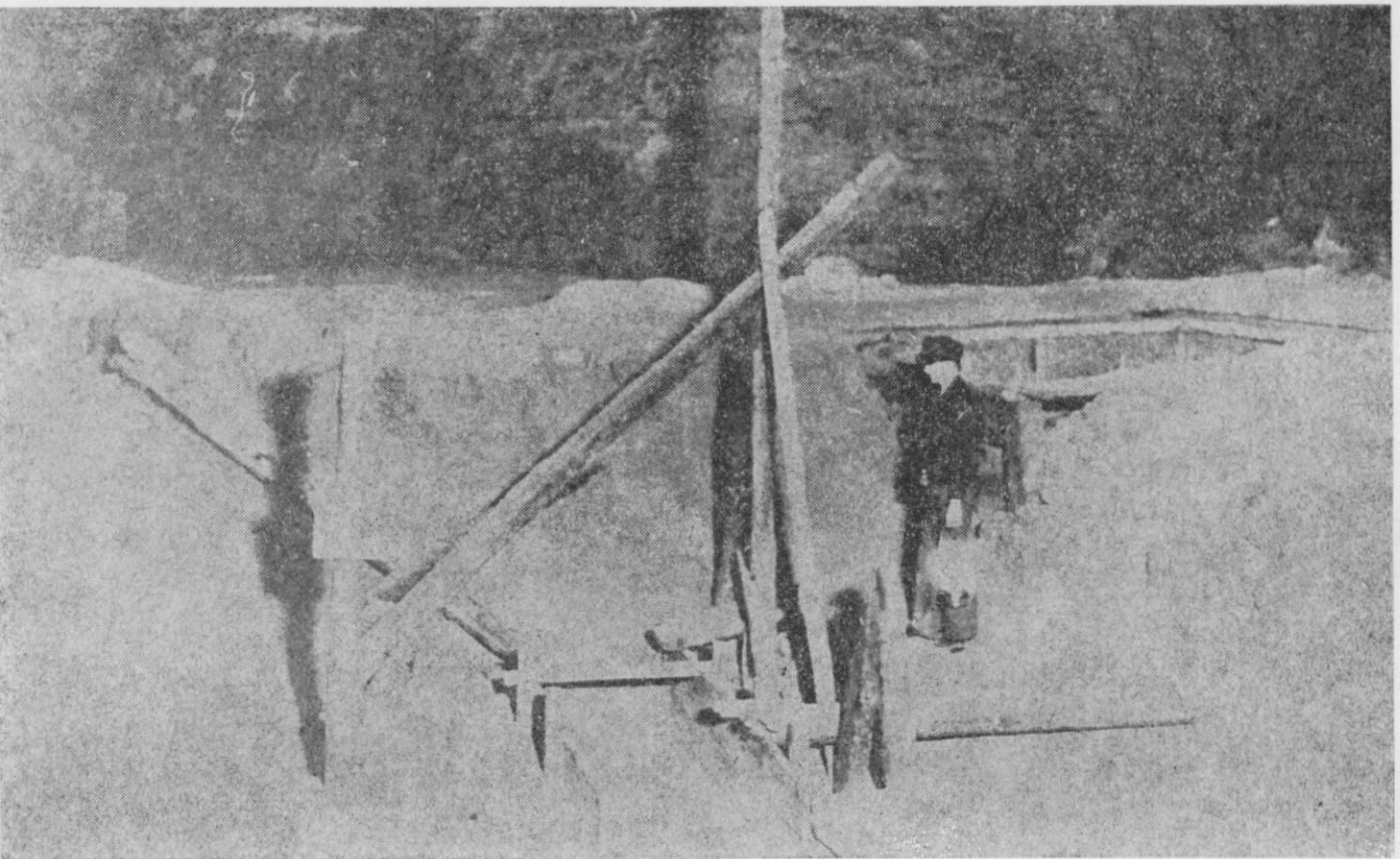
LEACHING VATS

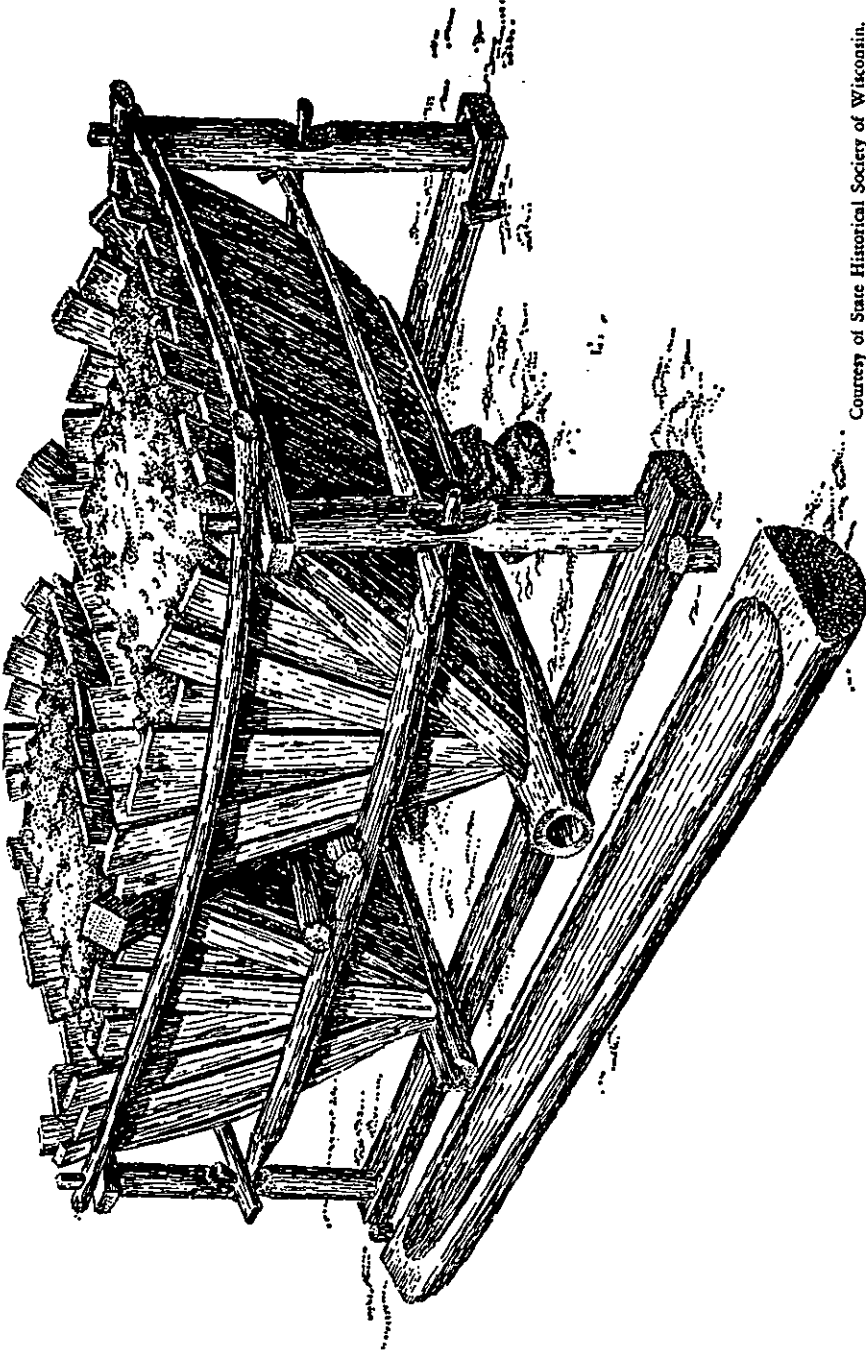
Even a cursory inspection of the spots selected for the erection of the various pieces of equipment used in the recovery operation indicates that the most logical and convenient spots were utilized. The leach-vats or "hods" were readily accessible to the cave passageways in which the petre-dirt deposits were found since, as Miriam states, "Oxen were used for transporting the earth to the Hoppers for lixiviation." For many years wheel-tread tracks and oxen footprints were to be seen in some of the passages. The vats were positioned so that the fresh water piped from the surface would be delivered by gravity flow through branch lines erected along the tops of the vats. Spigots or valves were used to control the rate and amount of water flow to the individual vat. The collection center, the remains of which are shown on page 242, and the main pumping center were so located that most of the leach-brine flowed to this center by gravity, from the leach-vats, and from which it could most conveniently be pumped into another pipe line and would flow toward the surface. Apparently, at least one other relay pumping station must have been located closer to the boiling kettles, since an early visitor reported the presence of the ruins of a platform adjacent the cave entrance, upon which a pump could have been mounted. A reconstruction of the main pumping center is shown in a display in the Visitors' Center at the Cave.

The leaching vats used at the Mammoth Cave operation illustrate a rather highly advanced stage in the design of this type of equipment even over that which was used many years later. This was due to the fact that a large portion of the structure was made from hand-hewn or sawed planks, braces, studs, beams, and split boards.⁹ The picture on page 243 shows a reconstruction of a pair of V-shaped leaching vats of the mid-1800's period and are drawn to illustrate a number of variations in structural details. This sketch provides a basis of comparison with the form of vats used in Mammoth Cave. A more complete description of this vat is found in *Tools and Equipment of the Saltpetre Miners*.⁸ Helene⁹ gives an illustration and description of other variations of leaching vats, as used in France.

Thor Borresen, quondam Assistant Historical Technician for the United States National Parks Service, in a 1941 Report¹ presents a very comprehensive survey of the state of preservation of the recovery equipment and also shows some pictures of the leaching vats and pipe lines as they existed at that time. In his 1942 Report are photographs of some excellent drawings which show in great and exact detail the design and dimensions of the vats as originally constructed. He also provides copious notes of the kinds of woods and descriptions of how each structural element was prepared for use and discusses the assembly







Courtesy of State Historical Society of Wisconsin.

of the vats. His description of the vats is so complete the following is taken from his 1942 Report.

"All timbers such as frames, sills, and comings are of oak hewn out by hand. The poplar siding and flooring were ripped out by hand using the old pit or whip saw. On the vats in the Rotunda the inside of the siding was hand dressed. In Booth's Amphitheatre the inside of the siding and the flooring were dressed. All siding on all the vats was tongued and grooved. On the outside of all the vats the siding is rough and the marks of the old whip saw are amply indicated and easily identified. All the nailing studs measured from 3½" to 4½" in width, and from 4½" to 5½" in thickness. Some of the studs are hewn on all four sides. Others are partly hewn and partly sawed. The top whaling of coming timber is a piece of 3½" by 5½" hewn oak. The bottom frame timbers, to which the floor joist(s) and studs are mortised and tenoned, were hewn out of one triangular piece. The inside triangular groove was cut deep and wide enough so that the first board of the siding as well as the bottom board would partly overlap within the groove or rabbet. The sill frame on which the vat rested was hewn on the top and two sides only. The bottom remained in its natural shape of the log. The stone walls on which the entire wooden structure rested was laid dry. There were three longitudinal walls and one front and back wall. In thickness they vary from 16 to 20 inches long [*sic*]. The height depended on the bottom of the cave. They vary from 18" to 2' 6"."

The leaching vats, which were box-shaped, in general measured about 12 feet wide, 13 feet long, and 3 feet deep. Thus each vat would hold approximately 460 cubic feet of petre-dirt, which when saturated with water made a load of several tons on the floor of the vat. Thus, the floor had to be strong enough to support this load without appreciable warping. In addition, it had to be sufficiently water tight, and so constructed that it would catch the percolating water as it soaked through the petre-dirt and drain it to a collecting trough adjacent one end of the vat. These three functions were accomplished in rather an unique manner.

White oak logs closely uniform in size throughout their length and about 10 to 12 inches in diameter, were cut and then split into halves. The flat faces of these halves were hollowed, probably with a triangularly shaped or a round-nosed adz, about three to four inches deep throughout their lengths. This provided half-ring or semi-toroidal shaped log troughs which were used to construct the floors of the vats.

To construct the floor of a leaching vat, like those used in Mammoth Cave and in Big Bone-Arch Cave in Tennessee, the miners proceeded as follows: (1) a layer of the log troughs with the concave or hollowed

portion faced upwardly was laid as closely together as possible and fastened in position on the previously prepared foundation; and (2) a second layer of the hollowed logs, with the concave portion faced downwardly and positioned so the edges between the logs in the lower layer were spanned and covered by the hollowed portion of the upper layer, was added. Thus a strong, sturdy, water-tight floor similar to a tile roof was formed. The floor was sloped toward one end of the vat to provide a gravity drain for the collection of the leach-water. This structure is shown on following page.

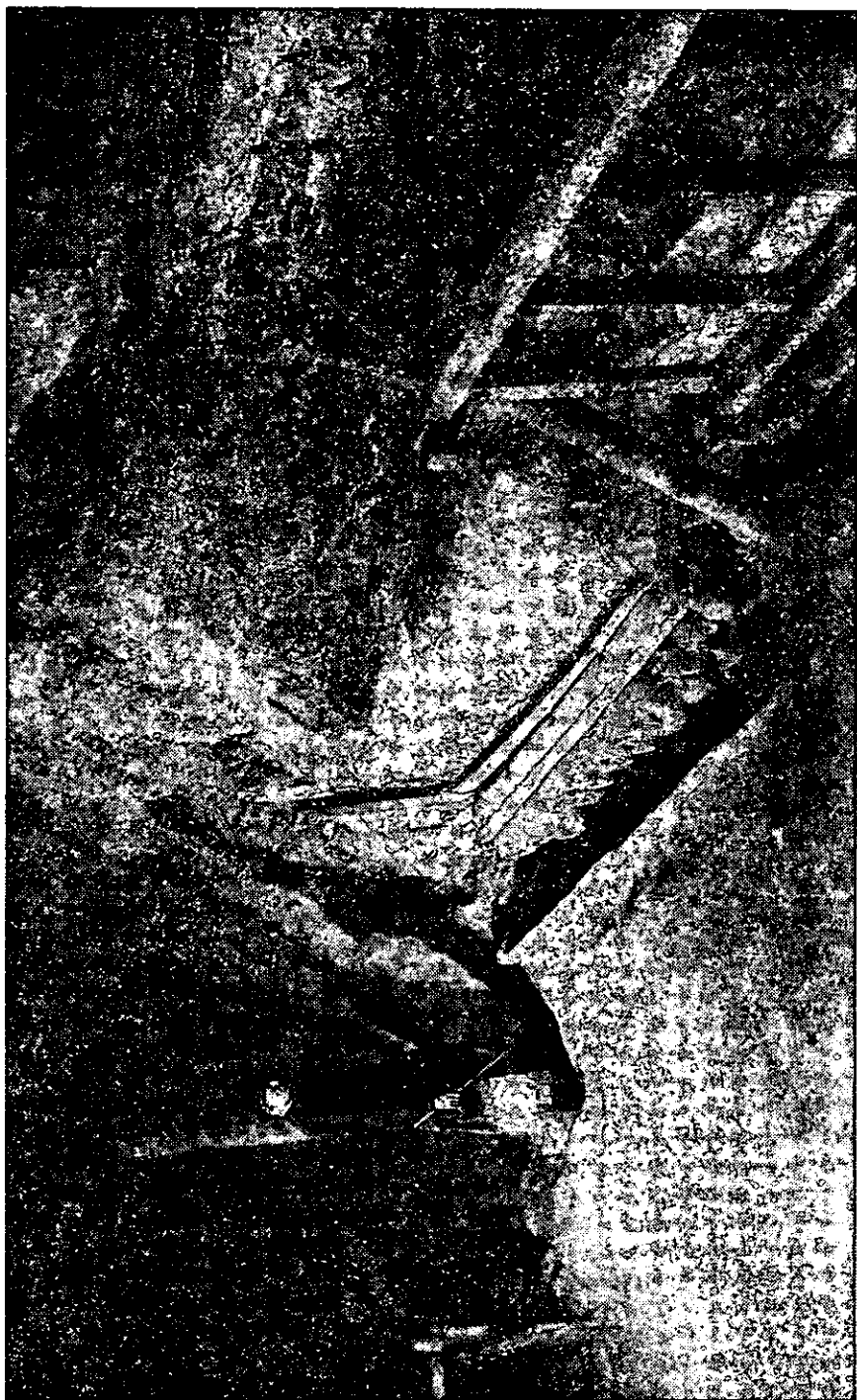
In order that the water might percolate through the petre-dirt, be collected and removed from the bottom of the vat it was necessary to provide some means to prevent the petre-dirt from filling the space between the logs of the top layer and thus clog the grooved or drain-channel portions of the lower layer. This required the provision of some sort of screen or filter bed through which the leach-water would pass, but retain the petre-dirt.

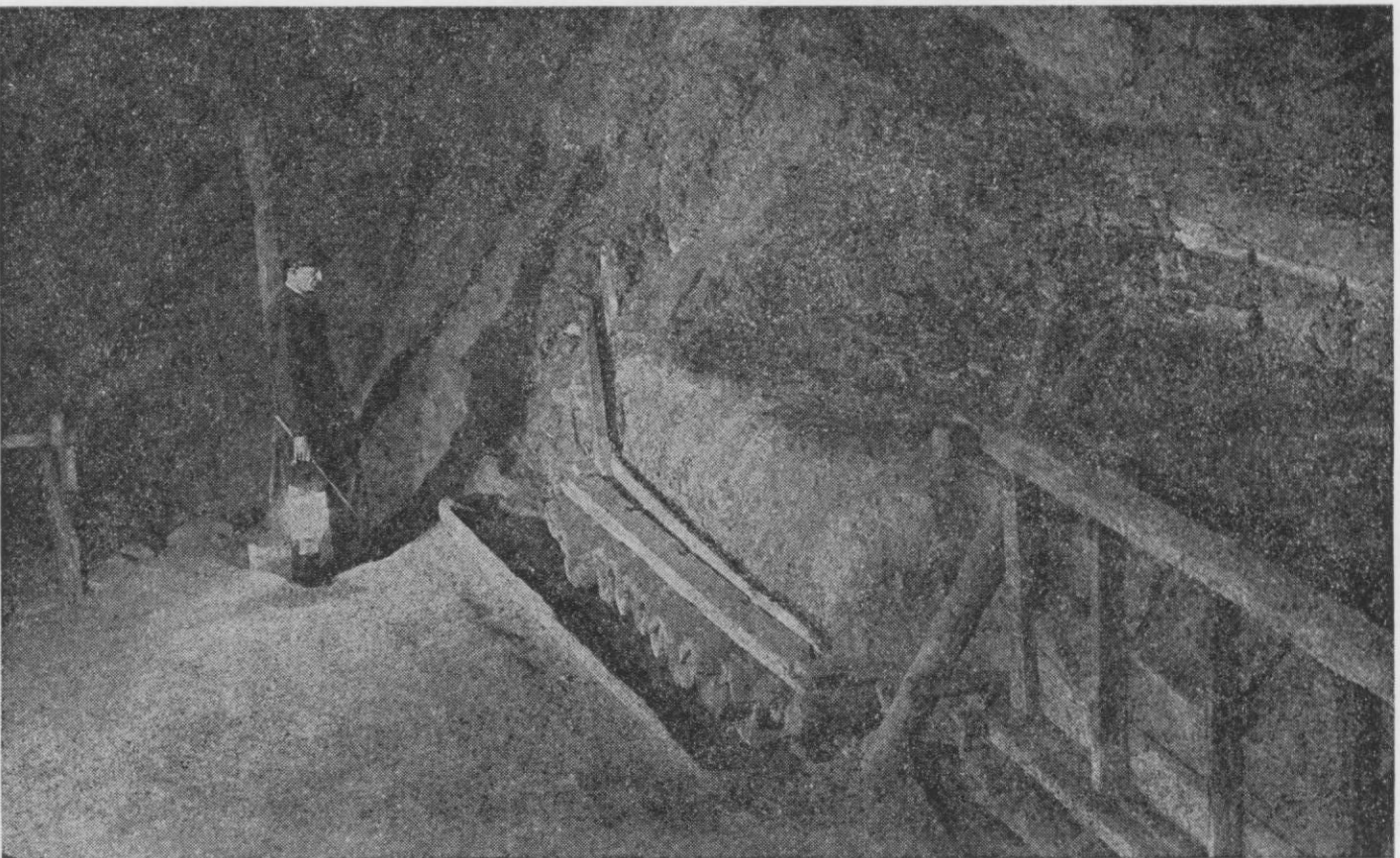
This screen or barrier was generally made by laying a mat of twigs, or sometimes cane reeds, on the floor to span the grooves between the logs, then placing a layer of straw or similar material on top of the twigs or reeds, and thus form a filter beneath the puddled earth and through which the leach-brine would drain from the vat. This leach-brine as it accumulated in collecting troughs adjacent the leaching vats was piped to or allowed to flow along graded lines to centrally located storage tanks from which it was pumped to the surface.

LEACH WATER COLLECTION AND HANDLING

Borresen, in his 1942 Report, makes the following statement: "Each vat had to be supplied with a continuous supply of fresh water. The water was constantly sprinkled over the azotized earth in the vat as seepage through it carried with it the saltpetre and nitre and became what was known as the *petre water*. This water would drain from the vat into a trough placed in front of each vat."

However, the present writer has not found in any saltpetre recovery installations which he has visited any evidence which indicates that the petre-dirt was kept under a constant spray during the leaching operation. In fact, quite the opposite has been observed. In dried casts of leached petre-dirt which have remained in the shape and size of the original leach vat, after it has rotted and almost completely disappeared, give evidence in the uniformity of the texture and its solidity, of having been thoroughly puddled during the filling operation and before the water had the chance to drain. In other instances where the leached dirt presents evidence of having been removed from the leaching vessel in the form of a thick mud, shovel and paddle marks have been clearly





preserved. Neither of these conditions would have prevailed unless the petre-dirt had been thoroughly and uniformly wetted. In fact, many of the early writers on this phase of the operation specifically suggest that the water be retained on the cave-earth for at least 48 hours before being allowed to drain.

Further, a consideration of elementary laws of physical chemistry gives support for such a puddling procedure. These principles were sufficiently well understood so that they were commonly practiced by the petre miners. *First*, the physical state of the petre-dirt was of such a nature that much of the leach-water, if added as a sprinkle, would follow cracks and crevices directly through loosely piled and chunky material. Thus the petre-dirt would not be thoroughly wetted. *Second*, soluble chemicals mixed in a bed of insoluble chunky material will be dissolved much more readily if the entire material is saturated and mixed, and the dissolving medium moves with a very slow percolating or almost capillarity rate through the bed and thus can remain in contact with the soluble material for a longer time.

After the leaching vat or "hod" had been filled with the petre-dirt, thoroughly saturated and puddled with fresh water to form a thick slurry, it was allowed to stand. During the next 24 to 48 hours as the water percolated and filtered through the slurry it would dissolve the cave saltpetre or calcium nitrate crystals which were mixed with the cave earth and carry it, in solution, to collecting troughs adjacent the drainage side of the vat, from whence it was transported to the collection center.

The remains of the open-topped, rectangularly shaped wooden tank toward which at least three drain lines are directed is clearly seen in the foreground of the picture on page 242. This tank, located in the room presently called *The Rotunda*, was as Borresen states, "built identical with (but smaller than) those used for leaching, except that it did not contain a false bottom or any drain outlets," was the collection center for the leach-water from all the leaching vats. It will be noted that this collection tank appears substantially intact except that the front end-boards are gone.

It appears clearly evident that during operation a pipe extended from the front of the collection box and was used to drain the leach-water from the trough adjacent the remains of the leaching vats shown on page 246. The pipe which rests on the back right-hand side of the tank served to conduct the leach-water from a second set of leach-vats located farther back and to the right. The third pipe at the back left-hand corner served to transport the leach-water from a third set of vats farther back in the cave, in the room presently known as *Booth's Amphitheatre*.

There was a second leach-water storage tank adjacent this third installation of leach-vats. This storage tank has been completely destroyed. However, Borresen was able to obtain rather accurate measurements of the dimensions of this tank from the casts of the dirt which, while wet, had been piled around it. He reports that this tank was much larger than the one in *The Rotunda*.

Even though practically nothing remains to indicate the existence of a pumping at this location except a number of timbers which have been mortised in such a manner that they could have been used as a framework or scaffold to support an elevated platform, it appears clearly evident that a pump was located above this second collecting tank. In addition, the grade on the lower one of the pipe lines carried on the stone pilasters as shown on page 240, and some other remaining remnants of equipment indicate a gravity flow line to the main collecting tank.

It is obvious that the storage capacity of the main collecting tank was small in comparison to the amount of leach-water produced. Therefore, it was necessary to provide some convenient means to get the nitrate-bearing water away from the tank, to the surface and to the boiling kettles. Since not only the collection tank, but a pumping station and a gravity flow line toward the entrance were involved, it was desirable that each of these be installed at the most logical and convenient locations.

Inspection of the cave ceiling directly above the remains of the collection tank reveals that sometime in the long ages past, a block of rock fell from this spot and left a dome-like hole the top of which is at a considerable higher elevation than the rest of the immediately adjacent ceiling.

Directly beneath this ceiling dome was the logical place to locate the collection tank. This extra head-room permitted the use of a higher-lift pump and the consequent location of the pipe line closer to the cave ceiling than was possible at any other location. Being able to get the pump end of the gravity-flow line higher would deliver the leach-water closer to the cave entrance. The entire plan of installation appears to have been conditioned by the existence of this ceiling dome. A sturdily constructed support tower with a platform adjacent its top, on which at least one man could stand, was erected above the collection tank. Remnants of the tower timbers may still be seen near this location. One report is that the tower was partly burned about 1903 by a torch which one of the cave guides threw upon it.

The pump body, which is still in existence, was made of a bored and squared log and had a conventional pivotally-mounted pump-handle at its upper end. To the inner end of the handle was hinged a pump-

rod which extended through the length of the bore and was fastened to a fitted piston mounted in and adjacent the lower end. The outside of the piston was fitted with a cup-shaped suction leather, with the inside of the cup faced upwardly. The weight of water above the piston would force the leather to bear against the inner wall of the pump-bore and thus prevent back flow. Over an axial hole through the piston, a weighted one-way flap valve was fitted. This valve would open on a downward stroke of the piston and allow water to flow through. On the upward stroke, the valve would close and lift the water in the bore above the piston. An intake valve was provided, adjacent the lower end of the pump body, but well below the top level of the water in the collection tank. Above, but near this opening, a flap-type, foot-valve was mounted and arranged to operate in a sequence opposite to that of the valve on the piston. Thus the foot-valve would open during the upward stroke of the piston and water would flow into the lower end of the pump body. On the downward stroke the foot-valve would close, trap the water, force the piston valve to open, and allow it to flow to the top of the piston. The repetition of this cycle of operation would lift water to the pump outlet located near the upper end of the pump.

The pump was mounted in the frame of the tower and solidly braced in position. The pipe line with its inlet connected to the outlet of the pump was supported and graded so the leach-water would flow toward the cave entrance. The pumping station was ready for operation.

Since the point to which the pipe line from the pumping station delivered the leach-water was well below the surface at the cave entrance it was necessary to use some additional means to complete the job and get the leach-water to the boiling kettles. The only presently-known authentic primary source of information relative to the manner in which this was done is found in Ebenezer Miriam's statement, "... the same mode of conveyance (wooden pipe lines) was resorted to, to convey the nitrate solution from the Hoppers to the mouth of the Cave, from whence it was raised by pumps. . . ."²

Robert B. Bird,¹⁰ in his flowery description of Mammoth Cave, which was published in 1835 only 25 years after the mining operation was abandoned, makes some interesting statements. In his description of the cave entrance is found, "... the pit immediately under the spring of the arch, [is] loosely choked with beams, planks, earth, and stones;" He further states, "A singular addition is given to its dreariness by the presence of several mouldering beams of wood stretched across the mouth from ledge to ledge; and two tottering chimneys of stone, behind the cotton-wood tree on the right hand, the ruins of the old saltpetre works." The only reasonable explanation of this type

of ruins is that the "beams of wood" were placed there to support a platform of some type and for some specific purpose. Even though no trace of any such ruins or any artifacts remain from which one might obtain information of the construction or even the existence of such a second pumping station, it appears that these two reports (Miriam and Bird) provide an ample basis for such an assumption.

WOOD AND TIMBER SUPPLY

An ample supply of timber was necessary to the operation of a cave saltpetre mining and recovery operation, for at least the following reasons: (1) to provide logs and lumber from which the leaching vats, brine collecting tanks and troughs, bridges, pumps, pipe lines, walkways, wagons and carts were constructed; (2) to provide fuel for the boiling kettles (The writer knows of no instance in which coal was used as a fuel.); (3) to provide ashes from which the conversion alkali was leached (The function of this alkali will be discussed later.); (4) to provide wood from which tools such as gluts, shovels, scrapers, paddles, rakes, stirring hoes, kegs, buckets, piggins, cooling and crystallization troughs, and other small tools could be made. Metal tools such as axes, wedges, frows, sieves, also scumming and dipping ladels were expensive and not readily available. Diderot¹ in his article, published in 1790, illustrates a number of tools used by the saltpetre miners and processors.

There seems to be no definite information of the source from whence the great quantity of wood used at the Mammoth Cave saltpetre recovery operation was obtained. Wm. N. Blane¹² who visited Mammoth Cave in 1822 said: "For several miles before arriving the road passes through a chain of low hills covered with short stunted timber, from these circumstances called by the people *The Kentucky Barrens*." However, it must be remembered that Blane did not visit Mammoth Cave either before or during the time when the saltpetre recovery operations were in progress and consequently could not have any first-hand knowledge of the amount of forest originally present.

Ebenezer Miriam, who was at the cave during the time the recovery operation was in progress, reports: "The Mammoth Cave extends under a range of knobs which border what is called the Green River or Kentucky Barrens. Formerly these Barrens were destitute of timber, but were covered with grass and flowers which grew spontaneous and with great luxuriance. Since that section has become thickly settled, the fires which every year overrun the surface consuming dry grass, &c., have been prevented, and now the surface is covered with a young growth of timber consisting of oak, hickory, and chestnut."²

The hard woods, such as the different kinds of oaks, hickory, chest-

nut, and rock-maple, provided the best material from which to build the framework for leaching vats, crystallization tanks, collection troughs, hand tools, wagons, and carts. Generally speaking, the ashes of these hard woods contain a greater percentage of alkali than do the pines and other soft woods. The straight grained white oak was used to make pipe lines and conduits. Some soft woods, such as poplar, were used to make boards and planks. Hickory was used to make ladders, handles for axes, shovels, and other similar tools. Withes of hickory were oftentimes used to bind and hold ladders in place. Thus it is evident that the craftsmen of the time needed a variety of woods which were suitable for different uses.

Miriam's and Blane's reports seem to indicate that timber was not present in any great quantity in the immediate vicinity of the cave. Therefore, it appears reasonable to assume that the woodcutters, as was also the situation at many other saltpetre caves, had to travel a considerable distance to find enough wood to meet the demands.

BOILING FURNACES

After the cave earth had been leached and the leach-water transported to the surface outside the cave it was necessary to concentrate and treat this solution of calcium nitrate, which was sometimes called *beer* and sometimes *liquor*, in order to remove the lime, sea-salt, organic matter, and other impurities which were present. It was also necessary to chemically convert the cave saltpetre or calcium nitrate to the gunpowder saltpetre or potash nitrate.

Due to the paucity of records the exact processes used in the recovery and purification procedures at Mammoth Cave are not known. However, the different steps which had been generally followed by the saltpetre makers, for many hundreds of years, were well understood and any slight suggested variation from actual practice is inconsequential. The final object, in any event, was to procure sufficiently pure saltpetre which could be used in the manufacture of gunpowder.

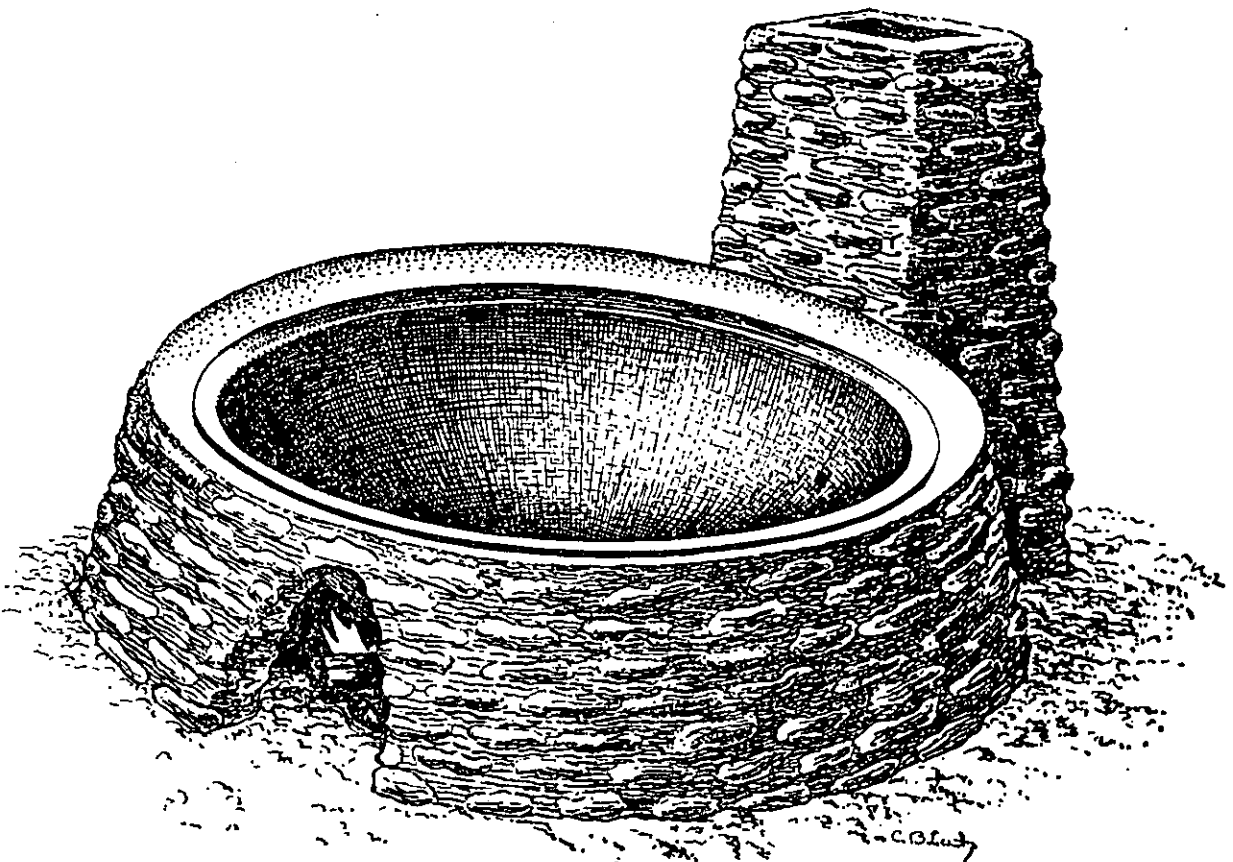
One of the most important pieces of equipment used in the concentration step was the boiling furnace with its attendant kettle. Evaporation pans and furnaces have been used for many years, and still are, in the practice of many crafts, i.e., to concentrate solutions of recovered chemicals, such as salt and saltpetre, as well as sugar, molasses, extracts of roots, barks, and herbs. Neither the shallow, flat-bottomed, rectangularly-shaped, sugar or molasses evaporating pan, nor those boilers used in the recovery of organic materials such as alcohol, or mint-oil, were suitable to handle either salt or saltpetre. Consequently these forms may be eliminated from consideration in a discussion of the particular type of boiling vessel used in the production of saltpetre.

Since the same form of boiling kettle was used at both the salt and saltpetre recovery plants only this type will be considered as the form used at Mammoth Cave. Such kettles were generally made of cast iron. However, during the American Revolution, at a powder factory in Massachusetts, in which Samuel Adams, Paul Revere, and Thomas Crane all had a hand in its design, construction, and operation, copper boiling kettles were used.¹

A considerable quantity of the crude saltpetre produced at Mammoth Cave during the War of 1812 was shipped to the du Pont powder factory at Wilmington, Delaware. The boiling kettles and furnaces used in the refining operation at this factory have substantially the same design and construction as described and illustrated by Diderot.¹¹ A drawing of a reconstruction of a boiling furnace and kettle is shown on opposite page. The chimneys shown in the picture of the "Entrance to Mammoth Cave," published in Part I of this article (January, 1967 issue of the *Quarterly*, p. 8), are higher than the one in the drawing. The only advantages of the higher chimneys are: (1) to produce greater draft and thus a hotter fire; and, (2) to keep the smoke farther away from the fire-tenders and other workmen.

The saltpetre (or salt) boiling kettle may range in size from 20 to 500 gallons. It is substantially hemispherical in shape and has no feet so it cannot stand upright by itself. It does not have ear-lugs to which a bail may be attached to suspend it from a tripod or to be slung over a pole that it may be hung over an open fire. It has an inwardly and downwardly inclined flange which extends completely around the periphery of its open top. These structural features provide a number of favorable advantages which are evident from a study of the drawing shown on opposite page. It will be noted that the kettle is suspended, entirely within the fire-box stone work, by the peripheral flange or rim. The absence of ear-lugs permits a smoke-tight, symmetrical joint between the kettle and its support. These features allow the heat to have full play over and to reach the entire outer surface of the kettle. The absence of feet and ear-lugs also eliminates possible hot or cold spots in the kettle which contributes to a more uniform heating and an increase in the operating efficiency.

This same type of boiling kettle was used, before 1790, at *Campbell's Salines*, near the present city of Saltville, Virginia, not only to concentrate salt brine but also saltpetre leach-water. One of these kettles may be seen on the Court House lawn in Marion, Virginia. The present author has a picture of a boiling furnace installation at Nickajack Cave, southwest of Chattanooga, Tennessee. Here the equipment was sheltered under a roof through which the chimney projected. Thus rain was kept from the fire and the fuel supply. Ralph Nelson Maxon¹⁸



pictures one such kettle which used to stand on the campus of the University of Kentucky, at Lexington.

MANUFACTURING PROCESSES

In the procurement of saltpetre from the earth of caves, or from any other source, the process, in general, involves the following steps: (1) Recovery, (2) Conversion, (3) Purification, (4) Crystallization, and (5) Refinement.

RECOVERY

Briefly and without elaboration the Recovery step in the manufacturing process reduced to its simplest terms was as follows:

1. Prepare a watertight container of any convenient size or shape, which can be drained from the bottom.
2. Fill the container nearly full of loosely piled petre-dirt.
3. While filling with dirt add sufficient water to cover and thoroughly puddle the mix to form a thick slurry.
4. Allow the mix to stand 24 to 48 hours to dissolve the calcium nitrate from the dirt. It should be stirred occasionally.
5. Drain the water from the container and pour it into a second container of fresh dirt.
6. Allow the second container to stand 24 to 48 hours. Then drain and put the leach water into a third container and let stand. By the time the water has percolated through the third batch of petre-dirt it will have dissolved sufficient nitrate that it will be ready for the next step.

There were almost as many variations in the details by which this procedure was implemented as there were different supervisors, at different caves. However, as at Mammoth Cave, all were directed to the same end, that is, to dissolve the saltpetre from the cave earth, in a manner not greatly different from the action of a drip coffee maker.

After the cave earth had been leached and the leach-water transported to the boiling kettles, the time had arrived for the really skilled workmanship of specially trained men to be used. These particular men were known as the *saltpetre makers* to differentiate them from the *petre monkeys*, that is the men who mined and leached the petre-dirt.

A large share of the labor employed in the saltpetre recovery project at Mammoth Cave, such as the miners, wood cutters, fire tenders, ash haulers, teamsters, and others of similar nature, could be classed as unskilled workmen. Also skilled craftsmen such as carpenters, coopers, wagon builders, and blacksmiths were needed. Others with special training included the necessary office, commissary, and administrative help. However, probably the most important individual, upon whom

the technical aspects of production, and thus the success of the operation depended, was the *saltpetre maker*.

The *saltpetre maker* had to have a clear understanding of a number of aspects of physics and chemistry. He had to know what chemicals were compatible and would produce a desired end-product. He had to be able to judge when a sufficient amount of a reagent had been used to produce the desired chemical reaction and thus not waste materials. It was also necessary that he understood the way in which a number of the Laws of Physical Chemistry processes could be used. Among these were filtration practices, differential and relative solubilities of materials, controlled and selective crystallization, and adsorption operations. These were utilized in order to separate the saltpetre from its contaminants such as insoluble material, precipitated lime, sea salt, organic matter, and other discoloring material. He also had to understand how to remove organic matter from the saltpetre by the promotion of scumming or controlled flash flaming with sulphur. Also he must know how the ranges in melting points of different materials could be used to remove unwanted chemicals.

That the *saltpetre makers* had all this knowledge and probably much more, for hundreds of years before the time the mining operations were in progress at Mammoth Cave, becomes clearly evident from even a cursory survey of the literature and the writings of the authorities on the practices in the art of recovery and refinement of saltpetre. While there are many other authorities who wrote in this field, only three, who were widely separated in time and places of residence, will be mentioned in connection with the probable recovery practices used at Mammoth Cave.

The three men, whose writings are considered but not reproduced in this study, are Agricola (1520)¹⁴, Diderot (1790)¹⁵, and Joseph LeConte (1862)¹⁶. Agricola's work, which is a presentation in the form of a Field Manual of the practices followed by the men who were engaged in the recovery and refinement of different minerals and metals, has been selected as representative of the knowledge of these crafts which had accumulated to that time. Diderot's *Encyclopedia*, of which he was the Editor, is a collection of discussions on many topics and by different authorities who were apparently generally contemporary. In all probability Lavoisier was the author of the section on saltpetre and its recovery. Considerable of the procedure used by the du Pont's at their powder factory, during the first three decades of the 1800's, appears to have been based on the Diderot item, and augmented by additional instructions and knowledge which young du Pont received while he was a student of Lavoisier. While the writings of LeConte, who was Professor of Chemistry and Geology at South Carolina College,

were published a considerable time after the saltpetre recovery operations at Mammoth Cave were terminated, reference is made to them to illustrate that the study of the production, recovery, and refinement of saltpetre did not become a lost art, but continued to be a concern of students of Chemistry. The fact that LeConte's writings contain substantially the same instructions for procedure as used for many centuries confirms the belief that the saltpetre makers were well above the average of the general craftsman in their skills and knowledge.

CONVERSION

Since the cave saltpetre or calcium nitrate, which had been dissolved from the petre-dirt and is in solution in the leach-water, is not suitable to be used in the manufacture of gunpowder, it is necessary to convert this calcium nitrate to potash nitrate. To do this requires the treatment of the solution with some potash chemical, which was known as pot or pearl ash or sometimes as fixed alkali. The potash will chemically convert the calcium nitrate to potash nitrate and cause the calcium to precipitate as lime. This was usually performed as follows:

1. Wood ashes are placed in a leach-hopper, wet with clear fresh water, puddled, and allowed to stand overnight. During this time the water dissolves the potash lye and potash carbonate which are present in the ashes.
2. The potash water is drained from the leaching vessel and strained through several layers of cloth to remove the undissolved matter.
3. The potash solution is now added to the previously filtered saltpetre leach-water. Potash is added only until the mix does not become cloudy. This step is watched very closely so as to hold the excess of potash to a minimum. This indicates that the precipitation of the calcium as an insoluble lime is complete.
4. The solution is now filtered to remove the precipitated lime. The filtrate contains the potash saltpetre and some other impurities such as salt and organic matter. It is now ready for the purification step.

PURIFICATION AND CRYSTALLIZATION

Purification, in general, means the removal of all contaminants, including water, which are present in any material. The saltpetre makers, as do the present-day chemists, strove to remove all possible foreign matter from the final crystalline product.

There was a considerable variation in certain details of procedure as recommended by the various authorities on saltpetre production and as practiced at different recovery and purification locations. However,

this procedure, stripped of certain refinements and reduced to its simplest and most elementary steps was as follows:

1. Put enough of the converted and filtered leach-water in a boiling kettle to make it about three-fourths full.
2. Boil to evaporate water. Periodically add sufficient leach-water to the boiling kettle to hold the water level about uniform. Continue to boil until crystals of sea-salt begin to precipitate and accumulate on the bottom of the kettle. Remove the accumulated salt, from time to time, by means of a perforated dipping ladel.
3. Continue boiling until a considerable quantity of salt has precipitated. Remove the hot water solution from the kettle and allow it to cool to about 100° F. Due to the differences in solubility of the salt and the saltpetre in the cooler water, most of the salt will precipitate while substantially all the saltpetre will remain in solution.
4. Separate the sea-salt by filtering and return the filtrate to the boiling kettle and continue the boiling operation.
5. Add glue, alum, or ox blood to the solution which will cause the organic matter in solution to form a scum and rise to the top of the boiling solution. Remove this scum with a scumming ladel.
6. Add chunks of raw turnips to the hot liquid. These will adsorb any dark coloring matter which is present. Remove these when discolored.
7. Continue boiling until the saltpetre crystals begin to form and shoot into the solution.
8. Remove these crystals with a perforated dipping ladel and put them in a draining vessel. Return the drained liquid to the boiling kettle.
9. After the volume of boiling liquid has been greatly reduced remove it from the kettle to a cooling trough or tank. Agitate the cooling liquid with a wooden hoe. This will cause the saltpetre to precipitate in small crystals.
10. When the liquid has cooled and the crystals have formed, separate the crystals from the supernatant liquid, by draining and filtering, and return the liquid to another batch of boiling liquid.

The recovered saltpetre crystals, after having been dried over a slow fire or in the sun, were ready to be packed in bags or kegs and transported to a central location for the final or refining step.

REFINEMENT

In the final or Refinement step in the production of saltpetre of sufficient purity that it was satisfactory for use in the manufacture of gun-

powder, there were two procedures available. Each procedure was rather complex and the men who utilized either operation needed a rather complete understanding of how to control the physical-chemical processes involved. Therefore, it was a common practice to ship the impure saltpetre to special installations for this final treatment. Such treatment plants were oftentimes located adjacent to or a part of gunpowder factories.

Major George Washington Rains, a member of the staff of the Confederate Nitre and Mining Bureau, published in 1861 a field manual which he called *Notes on Making Saltpetre from the Earth of Caves*.¹⁸ This booklet presents an outline of the various steps to follow in one of the refinement procedures. Even though it was not published until several years after the mining operation at Mammoth Cave had been terminated, it was a restatement of the practices which had been used by the saltpetre makers for several hundred years. Expressed in their simplest terms Rains' instructions were as follows:

1. Put one gallon of water for each 14 pounds of the crude saltpetre crystals in a boiling kettle until it is about three-fourths filled.
2. Boil the water for about two and one-half hours and remove the scum which rises to the top.
3. Add sufficient cold water to hold the level to the same height in the kettle.
4. Dip the hot liquor from the kettle and strain it through a cloth filter into a cooling tank.
5. Continually agitate the cooling liquor with a wooden rake. This agitation causes the saltpetre to precipitate in small crystals.
6. Remove the crystals from the cooling tank as they form and put them in a draining trough.
7. After draining overnight the crystals are put into a washing barrel until it is about half filled.
8. Fill the barrel with cold water and let stand one hour, then drain the water from the crystals.

This procedure give a nitre which "is nearly pure, . . . and can be made into gunpowder." However, for a top quality of saltpetre it is necessary to wash the crystals twice. All wash water and mother liquor which remains after boiling it not discarded but is returned to the boiling kettles for further treatment.

A second method which the saltpetre makers have also used, for many years, dates back to at least the time of Agricola. It will be remembered that he was busy collecting material for his *De Re Metallica* shortly after the time Columbus made his famous sea voyage. This

method does not make use of the principle of differential solution but does utilize some other physical-chemical phenomena. Reduced to its simplest form it was about as outlined:

1. A boiling kettle is filled about three-fourths full of dried saltpetre crystals and heated until the crystals melt.

Since the saltpetre crystals have a much lower melting point (337° F.) than the salt (805° F.) it will fall to the bottom of the kettle and can be removed with the proper dipping ladle.

2. Small quantities of glue, alum, or ox blood are added to the melted crystals.

These materials cause the organic matter which has not been previously removed to foam and gather on top of the melt as a scum. Since fats and oils comprise most of the foam and scum they cannot be readily removed with a scumming ladle. Powdered sulphur is sprinkled on top of the scum and set on fire. This controlled flaming will burn the scum and remove these contaminants.⁵

3. When the operator considers these reactions are complete the melted material is poured into cooling vessels and allowed to cool and harden.

These marble-like chunks were called "grou" saltpetre.

Some powder manufacturers preferred that these chunks be provided rather than the crystallized form. Thus they could control the crystal size when the "grou" was crystallized from solution.

4. To produce the crystallized saltpetre, the cakes after having been broken into small pieces were dissolved in a small quantity of hot water.
5. After straining through a cloth filter, the solution was run into a crystallization tank where it was constantly agitated during the cooling. The crystals were drained, washed and dried in the usual manner.

This process produces saltpetre which is reported to be well over 99% pure and can be used to make gunpowder of the finest quality.

An interesting sidelight, on the form in which saltpetre was shipped from the recovery and processing installations, was a general attitude expressed by gunpowder manufacturers. Most of them preferred saltpetre which had been refined by the melting process rather than by crystallization. There were several good reasons for this. As previously explained, in the melting process the crude saltpetre crystals were heated in a kettle until they were melted which is a much lower temperature than the melting point of sea salt. Because of this the un-

melted sea salt crystals would settle to the bottom of the kettle and would be strained from the melted saltpetre as it was poured into cooling vessels. Also, the organic matter was readily removed. Since the melted crystals were at a much higher temperature than the boiling point of water the occluded water was boiled out of the melt. In addition, with the material in chunk form there was less loss during handling and shipping.

CONCLUSIONS

Nothing is known relative to which, or if either, method of refining was used at Mammoth Cave. However, records do show that the du Pont company considered the saltpetre which they purchased from dealer Charles Wilkins, of Lexington, Kentucky, was exceptionally pure. Since Wilkins was one of the owners and operators of the project at Mammoth Cave, it seems reasonable that a considerable quantity of the saltpetre he sold came from this cave.

Even though there were a number of powder mills in various sections of Kentucky, five of which were in Lexington, there is nothing in the records to indicate that any gunpowder was manufactured at Mammoth Cave.

(To be continued)

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NOTES

1. On the occasion of a visit to this cave the owner told the present writer the following story:

Several years ago two ladies came to visit the cave. They had with them an elderly colored man. When they returned from their visit to the cave, the colored man said, "Yes ma'am. This is the cave where I rode a mule that carried bags of petre-dirt from the cave to the leach vats down yonder by the crick. The miners put bags of dirt across the back of the mules and us boys would ride out of the cave. Both white and colored boys rode mules."

m. There is a great possibility that this artist was Fleming Gatewood. Evidence is found not only in Miriam's report but in the Lee map (See Note o, below) of the cave that Gatewood had lived many years in this area and spent much time in the cave. The exact date upon which this map was drawn has not, to the moment, been definitely established.

n. Thomas Law migrated to America from England in 1794, settled in Washington, D.C. where he invested heavily in real estate. He tried to promote the erection of a gunpowder mill in the north edge of Washington. He married a granddaughter of Mrs. George Washington.

The original of this map is in the Winterthur Collection 1, Group 4, in the Eleutherian Mills Historical Library. The present writer wishes to acknowledge the kind permission granted him to reproduce this map. An extensive search has been conducted for the original correspondence between Thomas Law and Albert Gallatin relative the first mention of this map. However, to the moment such has not been discovered.

o. While copies of the Lee map are readily available the only copy of the *Notes* presently known is in the library of the Western Kentucky State College, Bowling Green, Kentucky. That portion of the *Notes* which is pertinent to this study are here presented. These were procured by Harold Meloy of Shelbyville, Indiana, who kindly made his personal copy available:

During the last war, and for many years previous, a large quantity of saltpetre was annually made at this cave. The remains of the works are still standing. There are two ranges of pipes, leading from the waterfall at the mouth, to the second hoppers; one range was used to supply the hoppers with water to leach the earth; the other served to convey the beer or water that passed through the hoppers to the furnace at the mouth, where it was boiled down, mixed with the alkali, and crystallized. Visitors often amuse themselves by conversing through these ranges of pipes. A person listening at one end may hear distinctly the smallest whisper from the other.

p. Daniel Drake (Oct. 20, 1785-Nov. 5, 1852) was an American physician and writer. He was a member of the faculty of the Transylvania Medical School, and founder of the Medical College of Ohio. He was born in Plainfield, New Jersey and died in Cincinnati. He moved to Mayslick, Kentucky as a small lad. Although educated in medicine he made an extensive study of mummies in caves and mounds in the vicinity of Cincinnati and in Kentucky.

q. The general distinction between a *board* or *shake* and a *plank* was as follows. A *board* or *shake* was split from a billet of straight-grained log, by means of a frow, and generally was not more than four feet long. A *plank* was sawed from a log, usually using a whip or pit saw, and was over four feet long.

r. A more detailed discussion of this event is found in the present writer's unpublished manuscript on *The History of Saltpetre*.

s. This flaming operation which was sometimes used to remove organic matter from the molten saltpetre is another example of the knowledge and skill of the men who practiced the craft of saltpetre maker. These men were sometimes called the *refiners*.

In the performance of this rather delicate operation, powdered sulphur was sprinkled on the scum which had gathered on top of the molten saltpetre. The sulphur which vaporized at approximately 238° F. immediately changed to its vapor state. Ignition of this sulphur vapor by means of a torch, caused it to burn the organic scum and the clear, molten saltpetre was left in the kettle.

Agricola describes a slight variation of this process. He states "Others refine saltpetre by another method, for with it they fill a pot made of copper, and, covering it with a copper lid, set it over live coals, where it is heated until it melts. They do not cement down the lid, but it has a handle, and can be lifted for them to see whether or not the melting has taken place. When it has melted, powdered sulphur is sprinkled in, and if the pot set on the fire does not light it, the sulphur kindles, whereby the thick, greasy matter floating on the saltpetre burns up, and when it is consumed the saltpetre is pure."