INVESTIGATION OF CHRISTY TITANIUM DEPOSIT
HOT SPRING COUNTY, ARK.

BY DONALD F. REED

United States Department of the Interior — December 1949
INVESTIGATION OF CHRISTY TITANIUM DEPOSIT
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* * * * * * * * Report of Investigations 4592

A Century of Conservation

1849 1949

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

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1/ Mining engineer, Rolla Branch, Mining Division, Bureau of Mines, Rolla, Mo.

Report of Investigations 4592
INTRODUCTION AND SUMMARY

During the first 6 months of 1948 the Bureau of Mines investigated the titania deposit on the Wynn O. Christy property in northern Hot Spring County, Ark. The property is situated in Magnet Cove, about half a mile north of the Magnet Store and U. S. Highway 270 (fig. 1). The purpose of the investigation was to determine the extent and grade of the ore body and to obtain a representative sample of the ore in as nearly natural condition as possible for use in metallurgical testing.

All of the titania that has been marketed from Arkansas mines has been in the form of rutile from a deposit about 2 miles west of the Christy property. The titania in the Christy property occurs principally as brokite, which, with fragments of novaculite, quartz, and limonite, is imbedded in red clay. It is difficult to recover a core of the material. Three types of drills - a diamond drill, a bucket drill, and a Baker cable-coring tool operated on a churn rig - were employed in an effort to procure proper samples in their natural state. The Baker tool was found to be the most efficient and to be capable of drilling to a depth of 150 feet, making 80 to 100 percent core recovery (fig. 8).

Total footage drilled was 1,536.9 in 21 holes, of which 7 were diamond-drill holes, 13 were bucket drill holes, and one was drilled with the Baker tool. The ore body was found to be 900 feet long, 500 feet wide, and more than 141 feet deep and contained 5.8 percent TiO₂ and 0.52 percent V₂O₅. Most of the deeper drill holes bottomed in ore, and there is a possibility that the ore may persist to a depth of several hundred feet.

The Metallurgical Division of the Bureau of Mines is conducting experimental work at the Mississippi Valley Experiment Station at Rolla, Mo., for the purpose of developing methods of concentrating and utilizing the ore.

ACKNOWLEDGMENTS

Field work was under the general supervision of Leon W. Dupuy, chief of the Rolla Branch, Mining Division, and under the immediate supervision, first of A. B. Needham and later of the author. Sample analyses were made, and beneficiation tests are now being made by the Rolla Branch, Metallurgical Division, R. G. Knickerbocker, chief. Samples were analyzed first at the Bureau pilot plant at Bauxite, Ark., W. A. Calhoun, metallurgist in charge, and the analyses were verified at the Rolla Laboratory. The metallurgical research was conducted by M. M. Fine at Rolla.

Through the cooperation of Harold B. Foxhall, Director, Division of Geology, Arkansas Resources and Development Commission, geologic maps of the area prepared by Verne C. Fryklund, Jr., were made available to the Bureau, and all drill cores were logged by Drew P. Holbrook.

LOCATION AND ACCESSIBILITY

The Christy deposit is in the S1/2, SW1/4, SW1/4, sec. 16, T. 3 S., R. 17 W., in northern Hot Spring County, Ark. It is situated about half a mile north of the village of Magnet, which is 8 miles north of Malvern and 14 miles
Figure 1. - General location map.
east of Hot Springs on the Malvern-Hot Springs highway U. S. 270. A graded gravel-surfaced road crosses the property. It is found at $34^\circ 27' 20''$ N. lat., $92^\circ 50' 45''$ W. long.

Two railroads, the Missouri Pacific and the Chicago, Rock Island & Pacific, pass through both Malvern and Hot Springs, the line of the latter about 4 miles south of the property.

An electric power line crosses the property, and a natural gas pipe line passes nearby.

**PHYSICAL FEATURES AND CLIMATE**

Magnet Cove, in which the Christy deposit is situated, is a small valley or basin enclosed by rather sharp ridges. The highest and sharpest ridges are on the north and west sides of the cove. The longer axis of the valley is from northwest to southeast. The altitude of the floor of the valley is 400 to 500 feet. The surrounding ridges rise to altitudes of 900 feet on the north and west and 600 on the south and east. Cove Creek and Chamberlain Creek flow from the northeast. They join in the northeast part of the valley and cut through the enveloping ridge on the south to flow into the Ouachita River, which flows east to a point south of the cove where it turns to the south. The Christy property is situated on the brow of a small hill on the east side of the cove at an altitude of 600 feet. Chamberlain Creek runs southwesterly along the western end of it through a small but deep gorge. Except where the land has been cleared for farming or mining, the area is thickly timbered with second-growth pine, oak, hickory, and gum trees.

Average annual rainfall in the area is 47 inches. The mean average temperature is 61 degrees.

**HISTORY**

The first report of the occurrence of rutile and brookite in the Magnet Cove area was made by J. F. Williams in 1890. Additional geological studies were made by Henry S. Washington in 1900 and Kenneth K. Landes in 1931.

The first-known attempt to explore the Christy deposit was made in 1913 by R. E. Perkins, acting for the Titanium Alloy Manufacturing Co., which held a lease on the property. The work consisted principally of driving an adit from Chamberlain Creek gorge on the west end of the property.

After the work supervised by Perkins stopped, the property passed through the hands of several parties and eventually was owned by John Inglis, who willed the property to his son, Foster Inglis.


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In 1941 the property was sold to the Malvern Lumber Co. of Malvern, Ark., which leased it to Wynn O. Christy and his partner, A. G. Peters. Christy was the owner of the lease at the time of the project.

There has been no production from the Christy deposit as yet.

DESCRIPTION OF THE DEPOSIT

Most of the Christy deposit is in the S1/2, SW1/4, SW1/4, sec. 16, T. 3 S., R. 17 W., Hot Spring County, Ark. A portion of the deposit extends southward into the NW1/4 of the NW1/4, sec. 21, T. 3 S., R. 17 W., which property is a portion of the J. H. Rutherford Estate, C. H. Rutherford, administrator, Malvern, Ark.

The only mine workings on the property are the adit driven in 1913 by the Titanium Alloy Manufacturing Co. and 32 test pits dug by Christy in 1942.

The adit runs in a southeasterly direction from Chamberlain Creek gorge, which is on the western end of the deposit. The adit has long since caved and become inaccessible. Its length is not known, but old residents who worked in it have reported that it progressively penetrated 75 to 100 feet of barren ground, 40 feet of titanium-bearing material, another 40 feet of barren ground, then ore to the face. Christy cleaned out and opened the adit for a length of 90 feet in 1942. He states that the end of the adit was in ore when he stopped work, but the ground was badly caved and the ore was not in place. No sample records are available.

Holbrook\(^5\) gives the following generalized geologic section of the Paleozoic formations in the Magnet Cove area, where the Christy deposit occurs:

<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Formation</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboniferous</td>
<td>Mississippian</td>
<td>Stanley shale</td>
<td>300 (+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot Springs sandstone</td>
<td>50 (†)</td>
</tr>
<tr>
<td>Devonian</td>
<td></td>
<td>Arkansas novaculite</td>
<td>700 (†)</td>
</tr>
<tr>
<td>Silurian</td>
<td></td>
<td>Missouri mountain shale</td>
<td>50-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bluyllock sandstone</td>
<td>0-500</td>
</tr>
</tbody>
</table>

According to Holbrook, "The regional structure is a group of tightly folded Paleozoic sediments intruded by the Cretaceous igneous rocks of Magnet Cove. A series of parallel anticlines and synclines trend roughly northeast-southwest and plunge to the southwest (fig. 2); locally, the Magnet Cove intrusives have truncated one of these plunging anticlinal lines. This truncated antcline is overturned to the north, and ore deposition has taken place in the north limb.

The formations in the north limb of the anticline trend S. 75° W., dipping about 65° southeast. Within a few hundred feet of the intrusive, however, they gradually shallow in dip and approach an east-west strike. The developed brookite deposit lies within the Arkansas novaculite formation and consists of

\(^5\) Holbrook, Drew F., A Brookite Deposit in Hot Spring County, Ark.: Bull. 11, Arkansas Resources and Development Commission, 1947, pp. 7-11.
Figure 2. - Geologic map, Magnet Cove area.
Figure 3. - Drilling on Christie titanium deposit.
a loosely consolidated, red, clayey material, with fragments of porous clusters of quartz crystals and coarse-grained metamorphosed novaculite. Dark-red clays compose the major portion of the deposit from the surface to a depth of about 10 feet. Below that depth, lenses of a very fine white to blue-white clay are encountered. These lenses vary in thickness from several inches up to 3 feet, and their orientation does not seem to correspond to the surrounding structural trends."

CHARACTER OF ORE

Holbrook\(^6\) states that the titania is found principally as subhedral brookite crystals in the porous, metamorphosed novaculite, in quartz veins, and disseminated with the crystal fragments in clay, with individual brookite crystals ranging from several millimeters to over a centimeter in length. The presence of pseudobrookite, minute needles of rutile, and leucoxene in the quartz grains has been noted. Limonite and hematite are found as a cementing agent in the porous novaculite and clay.

A composite sample, which represented grab samples from all of the test pits, was analyzed\(^7\) with the following results:

<table>
<thead>
<tr>
<th>Element</th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO(_2)</td>
<td>66.26</td>
<td>CaO</td>
</tr>
<tr>
<td>P</td>
<td>0.119</td>
<td>BaO</td>
</tr>
<tr>
<td>S</td>
<td>0.011</td>
<td>MgO</td>
</tr>
<tr>
<td>Fe(_2)O(_3)</td>
<td>14.9</td>
<td>Li(_2)O</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>6.54</td>
<td>K(_2)O</td>
</tr>
<tr>
<td>ZrO(_2)</td>
<td>0.04</td>
<td>Na(_2)O</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>7.56</td>
<td>Ig. loss</td>
</tr>
</tbody>
</table>

In April 1945, 20 check samples were taken from nine of the test pits by T. M. Ramslo, an engineer of the Bureau of Mines. At the time this sampling was done, it was impossible, because of water and caving of the walls, to sample to the original bottom of the pits. Results are given in table 1.

The test pits were again sampled in January 1947 by engineers\(^8\) of the Bureau of Mines. Channel samples totaling 2,900 pounds were taken from 21 pits. A composite was made and analyzed as follows:

<table>
<thead>
<tr>
<th>Element</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO(_2)</td>
<td>6.9</td>
</tr>
<tr>
<td>Fe</td>
<td>8.4</td>
</tr>
<tr>
<td>SiO(_2)</td>
<td>69.5</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>6.9</td>
</tr>
<tr>
<td>V(_2)O(_5)</td>
<td>0.44</td>
</tr>
<tr>
<td>S(^8)</td>
<td>1/0.05</td>
</tr>
<tr>
<td>P</td>
<td>1/0.05</td>
</tr>
</tbody>
</table>

\(^6\) See footnote 5.

\(^7\) Analysis by T. W. Carney, chief chemist, Arkansas Resources and Development Commission, Little Rock, Ark.

\(^8\) G. H. Johnson, O. M. Bishop, and T. A. Jones, Rolla Branch, Mining Division.

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<table>
<thead>
<tr>
<th>Pit No.</th>
<th>Depth sampled, feet</th>
<th>TiO₂ percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-1</td>
<td>0-3 3-7</td>
<td>8.2 6.0</td>
</tr>
<tr>
<td>6-5</td>
<td>0-3 3-7</td>
<td>4.7 4.6</td>
</tr>
<tr>
<td>5-4</td>
<td>0-1.5 1.5-8</td>
<td>7.3 10.2</td>
</tr>
<tr>
<td>4-1</td>
<td>0-3 3-8</td>
<td>6.9 8.2</td>
</tr>
<tr>
<td>4-5</td>
<td>0-3 3-11.5</td>
<td>6.7 5.6</td>
</tr>
<tr>
<td>2-3</td>
<td>0-5 5-10</td>
<td>7.3 5.6</td>
</tr>
<tr>
<td>1-1</td>
<td>0-3 3-7.5 7.5-17.5 17.5-27.5</td>
<td>5.5 17.2 7.3 11.5</td>
</tr>
<tr>
<td>1-4</td>
<td>0-5 5-7.5</td>
<td>4.9 6.9</td>
</tr>
<tr>
<td>Bank 2</td>
<td>0-7 7-10</td>
<td>8.4 13.2</td>
</tr>
<tr>
<td>Weighted average</td>
<td></td>
<td>1/8.0</td>
</tr>
</tbody>
</table>
Figure 4. - Diamond drill and water pump set-up using portable iron-pipe tripod.
Figure 5. - Bucket drill moving onto new set-up.
Figure 6. - Typical buckets.
will be covered in a subsequent publication. The Bureau is continuing its work on utilization of Arkansas titanium minerals for welding rod coatings and titanium metal.

WORK DONE BY THE BUREAU OF MINES

The first problem that confronted the Bureau was the choice of a drill that would be capable of (1) recovering representative samples of the ore that could be used in metallurgical research. This problem has been ably discussed by Dupuy. 2/ It was essential that the samples be so taken that the natural characteristics of the ore remain unaltered as these characteristics are determining factors in devising beneficiation processes. (2) The drills also should be capable of penetrating layers of sandy clay, clay, and hard rock and (3) penetrating to depths of at least 150 feet. Work previously done by the Bureau in the Magnet Cove area 10/ showed that a churn drill, although capable of meeting requirements (2) and (3), could not fulfill the first requirement. In the churn-drill sludges, the physical character of the ore minerals had been altered.

Preparatory work started in December 1947, but drilling was delayed by bad weather and did not start until January 12, 1948. A diamond drill (fig. 4) and a series M-type, double-tube core barrel were used. In this core barrel, which was designed to improve core recovery in soft or broken ground, the core lifter or retaining spring operates inside a core shell attached to the inner barrel. The inner barrel is suspended on ball bearings and is free from the rotation of the outer barrel, which carries the cutting bit. It extends down close to the face of the bit. Thus, the core passes into the nonrotating inner barrel immediately above the cutting face of the bit and the tendency of the core to grind upon itself or block the barrel is greatly reduced. Also, the area in which the circulating drill water comes in contact with the core is much smaller than that of a standard core barrel, and washing away of core minimized.

The first attempts to procure a core were not altogether successful. Core recoveries ranged as high as 60 percent. Sludge samples were recovered by advancing the casing to the bottom of the hole after each run, but, as in the case of the churn-drill sludges, they were not suitable for metallurgical testing.

In the latter part of January a combined foundation exploration rig or bucket drill mounted on a four-wheel drive truck was procured (fig. 5). The rig provided for both rotary and churn drilling. It was equipped with a spudding beam, 32-foot collapsible steel derrick with shock-absorbing crown pulley, a 7-ton double-drum hoist, small single-drum hoist, and string of regular churn-drilling tools as well as a rotary table, kelly, and drilling buckets. Power was supplied by an auxiliary gasoline motor. The 30-inch rotary

10/ Spencer, Robert V., Exploration of the Magnet Cove Area, Hot Spring County, Ark.: Bureau of Mines Rept. of Investigations 3900, September 1946.
table was mounted on the back of the drill frame to drive an auger bucket through an extension shaft and counter shafts. Buckets used were 20 inches in diameter and 18 to 24 inches long (fig. 6). A trapdoor auger bucket was first used, but it would not cut through the hard quartz clusters found in the ore. An open-bottom sawtooth bucket with the cutting edges of its teeth reinforced with hard metal was substituted, and better results were obtained. The bucket samples of the unconsolidated material were satisfactory, but the bucket bits would not cut through the ledges of hard rock. When one of these ledges was encountered, a 20-inch Mother Hubbard bit (fig. 7) was used, together with the churn mechanism rather than the rotary. Once through the ledge, which might be several inches or several feet in thickness, rotary drilling was resumed with the bucket bit. Thirteen holes ranging in depth from 15 to 61 feet were drilled with this rig. The average depth of bucket-drill holes was 41 feet, and the total depth was 531.5 feet. The drill cut a core 20 inches in diameter, which averaged about 270 pounds in weight for each foot of depth of material, and the core was preserved in its original character, except when it was necessary to use the Mother Hubbard bit. Cores were combined for intervals, usually 5 feet, and coned and quartered to obtain a sample that would weigh 50 to 60 pounds. Composites were made up from these samples for metallurgical testing.

Although samples obtained by the diamond drill were not suitable for metallurgical tests, the holes drilled by bucket drilling provided an excellent metallurgical sample. Seven holes were diamond-drilled for the purpose of determining the grade and extent of the ore body below the depth to which it was possible to drill with the bucket drill. In addition, two of the bucket-drill holes were deepened by the diamond drill. As work progressed on the project, more efficient techniques were developed for the diamond drill, and core recovery was improved. It was found that the best recovery was obtained by cutting the water pressure on the drill to the minimum required to keep the bit clear of cuttings while maintaining a constant bit pressure and a low speed of rotation. A low rotating speed was essential for the reason that when the rotating speed was increased, it was necessary to increase the pressure and volume of the water to avoid burning the bits, causing a higher loss of core by washing. A high rotating speed also caused a high loss of diamonds from the bits when a quartz cluster was encountered.

Near the end of the job, a Baker cable tool core barrel (fig. 8) was adapted to the bucket rig by utilizing the churn-drill mechanism with which it was equipped. One hole 82 feet deep was drilled with the Baker tool with very satisfactory results. It was found possible to drill to greater depth than with the bucket drill and to obtain 85 to 100 percent core recovery. The core obtained was 2-11/16 inches in diameter and large enough to be suitable for metallurgical testing.

The Baker cable-tool core barrel (fig. 8) consists of two main parts - an outer drilling barrel and an inner core-retaining tube. The drill barrel is composed of three parts - the drill barrel head, the main drill barrel, and a drill shoe or bit. The drill barrel head, which is screwed to the stem, contains a valve that opens on the upstroke; water rushes in through holes on the side; and on the downstroke the valve closes, forcing the water to the bottom of the hole, where the cutting is going on. The outer drill barrel is a seamless steel cylinder 8-1/2 feet long. The bits or drill shoes are 12
Figure 7. - Swinging the Mother Hubbard bit.
Figure 8. - Baker standard cable-tool core barrel.
Figure 9. - Removing core from Baker core barrel with hydraulic pump.
inches long and have 10 teeth faced with stellite. Watercourses are provided on the inside of the bit, permitting water to circulate between the drill barrel and the inner core tube.

The core tube also consists of three parts - the core tube head, the main core tube, and the trimmer shoe. The 13-1/2-inch tube head is expanded on the upper end to form a shoulder, which prevents it from falling through the bit. The core tube head is equipped with a ball check valve, which allows the water to escape while the core tube is filling with core; it also prevents direct water pressure on the core in the tube. The core tube is 7-7/12 feet long and is screwed to the head. The trimmer shoe screws on to the bottom of the core tube, is 3-1/2 inches long, slightly beveled on the bottom, and faced with stellite. On the inside of the shoe is a tapered trap ring, which retains the core.

In operation, the inner core tube does not lift off of the bottom of the hole. The outer drill barrel slides up and down over the inner tube, cutting a core 3-1/2 inches in diameter (fig. 9). This, in turn, is cut by the trimmer shoe to 2-11/16 inches in diameter. The core is pushed up into the inner core tube and held there by the tapered trap ring. Best results were obtained by running with a slower motion than is used in regular churn drilling. A speed of 25 to 32 strokes a minute was found to be about right. It was essential to run with a fairly "tight" line and keep the tools hitting evenly at all times to avoid a crooked hole.

The core was split, and half of it was retained for reference. The other half was split again, and one quarter was made up into samples for chemical analysis, and the other quarter also was made up into samples and placed in airtight cans for later use in making up the composite for metallurgical testing. Samples were analyzed for TiO₂ and V₂O₅, and weighted averages were calculated for each hole. Samples were prepared for analysis at the Bureau pilot-plant laboratory at Bauxite, Ark., under the direction of W. A. Calhoun. Analyses and check runs were made at both Bauxite and the Mississippi Valley Experiment Station at Rolla, Mo., under the supervision of R. G. Knickerbocker.

A composite sample from 11 of the bucket-drill holes gave the following results:

<table>
<thead>
<tr>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO₂</td>
</tr>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>SiO₂</td>
</tr>
<tr>
<td>Al₂O₃</td>
</tr>
<tr>
<td>CaCO₃</td>
</tr>
<tr>
<td>V₂O₅</td>
</tr>
<tr>
<td>Zn</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>P</td>
</tr>
</tbody>
</table>

A total of 1,536.9 feet was drilled in 21 holes. This includes footage in holes C-2, C-3, C-4, and ED-12, which were lost and had to be re-drilled. Altogether, 1,488.9 feet of hole was sampled. The area covered by the drilling was 900 feet long and 500 feet wide. The greatest depth attained by any of the drills was 141 feet in hole ED-4-D.
Core sizes and percent recoveries are given in table 2.

**TABLE 2. - Bit sizes and percent core recoveries for seven diamond drill and one Baker churn drill bit and core barrel**

<table>
<thead>
<tr>
<th>Diamond-drill hole</th>
<th>Bit size</th>
<th>Percent of core recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MK</td>
<td>EX</td>
</tr>
<tr>
<td>C-1</td>
<td>From 0</td>
<td>To 112.0</td>
</tr>
<tr>
<td>3-A</td>
<td>From 10.5</td>
<td>To 67.0</td>
</tr>
<tr>
<td>C-4</td>
<td>From 0</td>
<td>To 67.0</td>
</tr>
<tr>
<td>C-5</td>
<td>From 0</td>
<td>To 132.0</td>
</tr>
<tr>
<td>C-6</td>
<td>From 0</td>
<td>To 62.2</td>
</tr>
<tr>
<td>C-7</td>
<td>From 69.3</td>
<td>To 86.8</td>
</tr>
<tr>
<td>C-8</td>
<td>From 80.0</td>
<td>To 115.0</td>
</tr>
<tr>
<td>Baker BC-1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Locations of holes drilled are shown in figure 3. Drill hole logs and sample analyses follow.

**BIBLIOGRAPHY**


Fryklund, V. C., Jr., and Holbrook, Drew F. Titanium Ore Deposits of the Magnet Cove Area, Hot Spring County, Ark. Bull. 16, Arkansas Resources and Development Commission (in process of publication).

Reed, Donald F. Investigation of Magnet Cove Rutile Deposit, Hot Spring County, Ark. Bureau of Mines Rept. of Investigations 4593.
Figure 10. - Graphic logs, holes C-1 and C-3A.
Figure II. - Graphic logs, holes C-4 and C-5.
Figure 12. - Graphic logs, holes C-6 and C-7.
Figure 13. - Graphic logs, holes C-8 and BD-1.
Figure 14. - Graphic logs, holes BD-2 and BD-3.
Figure 15. - Graphic logs, holes BD-4 and BD-5.
Figure 16. - Graphic logs, holes BD-6 and BD-7.
Hole No. BD-8
Coord. N 10252, E 10485
Date Started 4-22-48
Date Completed 4-26-48
Collar Elev. 601.8'

Hole No. BD-9
Coord. N 10211, E 10248
Date Started 4-27-48
Date Completed 4-29-48
Collar Elev. 584.1'

Figure 17. - Graphic logs, holes BD-8 and BD-9.
Figure 18. - Graphic logs, holes BD-10 and BD-11.
Figure 19. - Graphic logs, holes BD-12 and BD-13.
Figure 20. - Graphic log, hole BC-1.