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BUREAU OF MINES TECHNICAL PROGRESS REPORT

EVALUATION OF A SHEATHED PERMISSIBLE EXPLOSIVE CHARGE FOR OPEN SHOOTING IN FLAMMABLE ATMOSPHERES

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U.S. DEPARTMENT OF THE INTERIOR

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ILLUSTRATIONS

EVALUATION OF A SHEATHED PERMISSIBLE EXPLOSIVE CHARGE FOR OPEN SHOOTING IN FLAMMABLE ATMOSPHERES

By Richard J. Mainiero [1] and J. Edmund Hay [2]

ABSTRACT

The Bureau of Mines has developed a prototype nonincendive explosive rock-breaker charge that can be fired unconfined in underground bituminous coal mines without the danger of igniting a flammable atmosphere that might be present. At present, unconfined shooting in underground coal mines is prohibited, but there are situations where the use of such shots would yield an overall improvement in safety. The charge consists of 1-1/2 lb of permissible water gel explosive in the form of a short cylinder 7 inches in diameter and 7/8 inches high, surrounded by a 1/2-inch-thick layer of damp salt, and encased in latex rubber reinforced with cheese cloth. The latex rubber housing provides a charge package that is strong enough to resist rough handling yet is pliable enough to conform to an irregular stone surface. A charge of this shape was found to be more effective at breaking rock than charges with lined or unlined cavities.

Incendivity tests in a gallery have shown that the prototype charge will not ignite a flammable methane-air atmosphere when fired. Rock-breaking tests made with limestone boulders indicate that the charge will satisfactorily break stone slabs weighing 1 to 2 tons, and that two or more charges might be effective for slabs weighing up to 10 tons.

In cooperation with the Mine Safety and Health Administration (MSHA), a test protocol for the certification of these charges as "permissible" for use in flammable atmospheres is being developed.

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INTRODUCTION

Because of the hazards associated with flammable methane gas and coal dust, the shooting of mudcaps (adobes) or other unconfined explosive charges in underground bituminous coal mines is prohibited; all explosives must be fired in stemmed boreholes. However, there are situations where it would be advantageous from a safety standpoint to fire unconfined shots. This would be in the areas of dislodging loose roof slabs, overhangs, rock-fall leveling, slab or boulder breaking, and crevice shooting. The Bureau of Mines has been developing an explosive charge that is nonincendive, meaning that detonation of the charge will not ignite a flammable atmosphere. This explosive charge could be applied to the blasting conditions mentioned earlier. The explosive charge has not yet been certified as "permissible" for use in flammable atmospheres, but the necessary protocol is being finalized with MSHA.

The purpose of this paper is to quickly disseminate preliminary information on the essential details of the research to the mining industry. More detailed information will be presented in subsequent publications.

EXPERIMENTAL PROCEDURES AND RESULTS

Charge Design

Research conducted by the Bureau of Mines has shown that a properly designed, prepackaged explosive charge could be safely fired unconfined in a flammable atmosphere if the explosive was covered with a layer of flame-inhibiting material, such as salt, that would be dispersed as a fine cloud upon firing. For an explosive charge of 1-1/2 lb, equivalent to two 1-1/4- by 16-inch cartridges of permissible water gel explosive, a 1/2-inch layer of salt proved to be adequate.

One question to be answered was the proper shape for the explosive charge. Charges of various shapes with lined and unlined cavities were tested with the result that the complexity and cost of these charges was not justified in terms of rock-breaking efficiency. The most effective charge was one in the form of a short cylinder 7 inches in diameter and 7/8 inch-high. This shape spread the explosive over a large surface area of the rock, yet provided a thickness adequate to provide for efficient detonation.

Based on the research described above, the charge illustrated in figures 1 and 2 was developed. The charge is covered with a 1/2-inch layer of damp salt (88% salt, 12% water), which in turn is encased in a housing consisting of latex rubber reinforced with cheesecloth. This configuration provides a charge package that is soft enough to conform to the irregular surface of a rock yet strong enough to withstand rough handling.

Incendivity Tests

The first step in the evaluation of the nonincendive charge was to determine whether it could be fired safely in a flammable atmosphere. To this end, incendivity testing was conducted in a "bombproof" bunker using a steel and plastic gallery 6 feet wide, 6 feet tall, and 8 feet long. Inside the gallery a 3- by 3- by 1-foot concrete block that served as a simulated boulder was set on edge, and the charge was taped to one of the vertical faces. Methane was added to the gallery, and the gas-air atmosphere was constantly mixed with a circulating fan and monitored with an infrared analyzer. When the gallery atmosphere stabilized at 9% methane, a sample was taken for analysis, the mixing and sampling apparatus were shut down, and the charge was fired with an instantaneous detonator. Ignition of the methane could be identified by the intense noise and vibration, which did not accompany nonignitions.

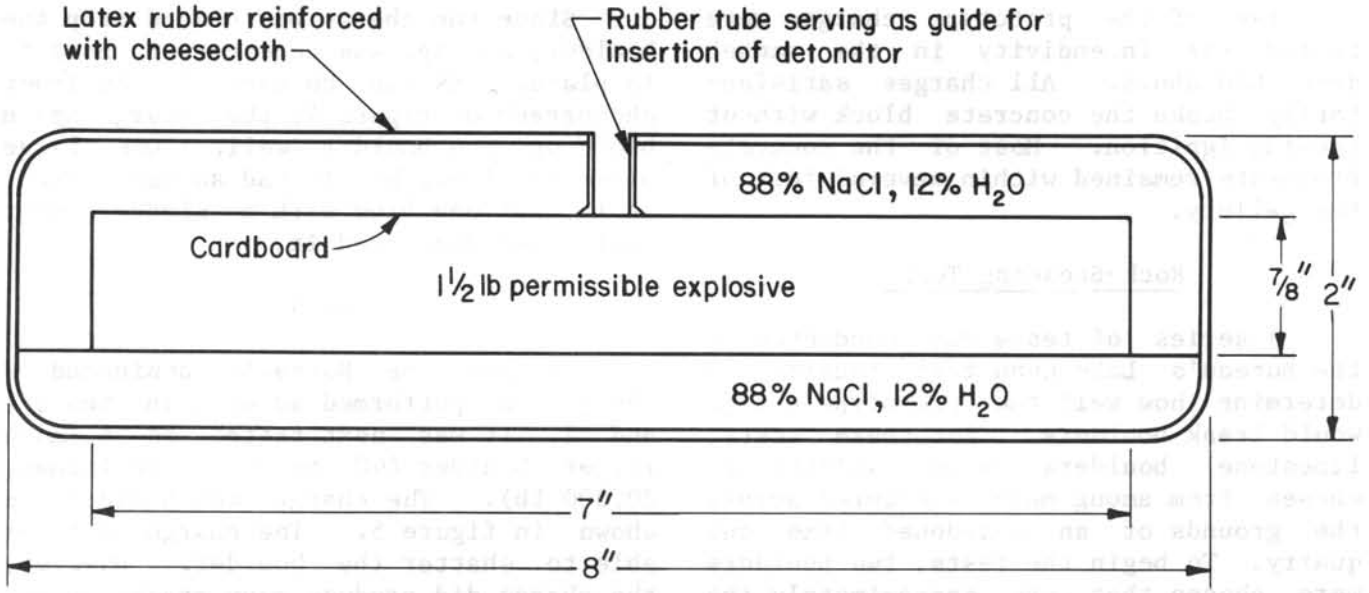

FIGURE 1. - Diagram of prototype nonincendive rock-breaker charge. (Later charges incorporate polystyrene rather than cardboard for inner explosive housing and may have an additional detonator well on the side.)

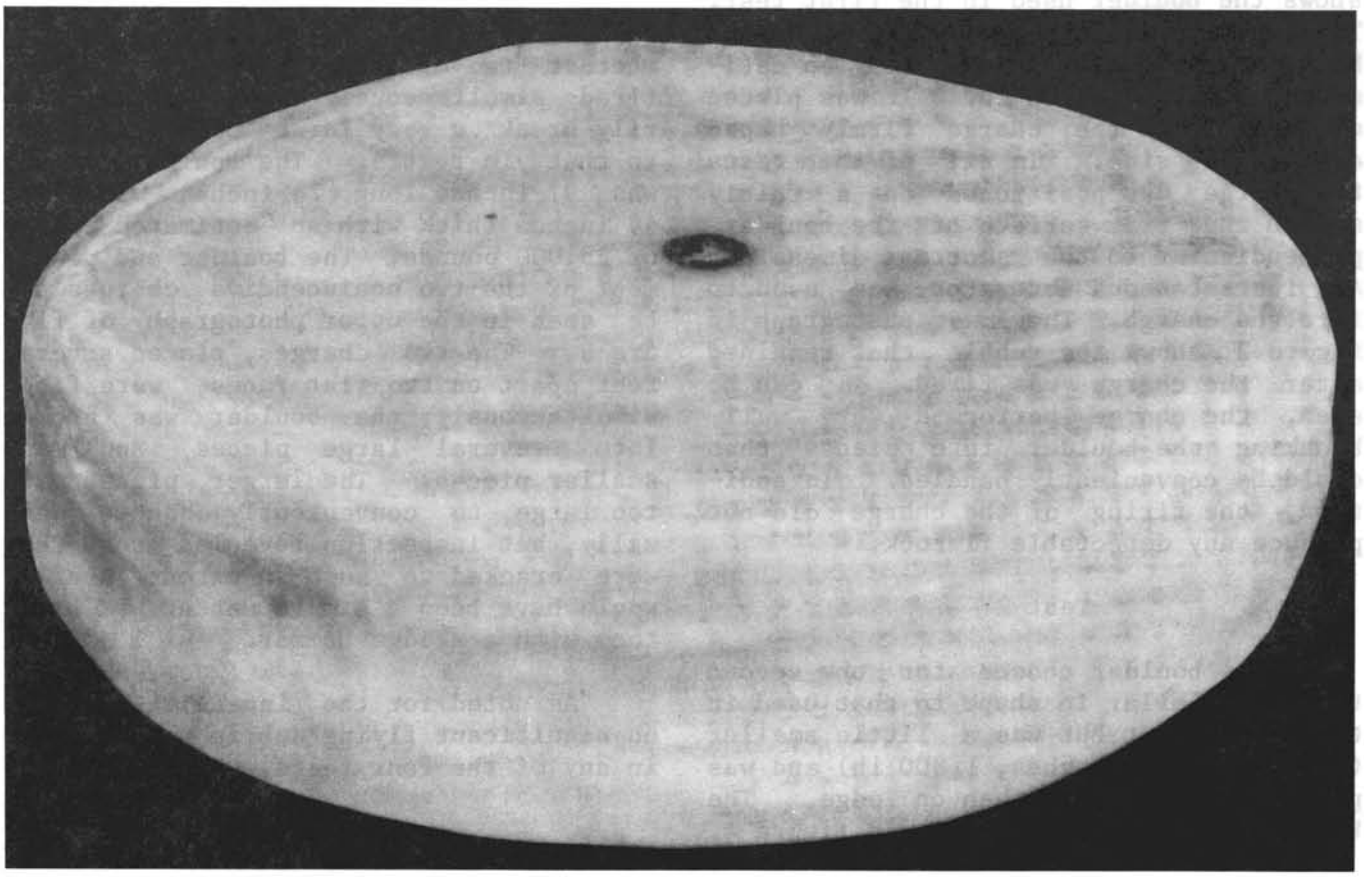

FIGURE 2. - Photograph of prototype nonincendive rock-breaker charge.

Ten of the prototype charges were tested for incendivity in the manner described above. All charges satisfactorily broke the concrete block without causing ignition. Most of the concrete fragments remained within several feet of the gallery.

Rock-Breaking Tests

A series of tests was conducted at the Bureau's Lake Lynn test facility to determine how well the prototype charge would break boulders. For these tests, limestone boulders were selectively chosen from among many scattered across the grounds of an abandoned limestone quarry. To begin the tests, two boulders were chosen that were approximately the same size as the concrete blocks broken in the incendivity tests.

Test 1

The upper photograph in figure 3 shows the boulder used in the first test. The boulder was 54 inches wide, 32 inches high, and 18 inches thick, with an estimated weight of 2,700 lb. It was placed on edge with the charge firmly taped against the side. In all of the tests the charge was positioned on a fairly smooth and flat surface of the boulder, perpendicular to the shortest dimension. An instantaneous detonator was used to fire the charge. The lower photograph in figure 3 shows the rubble that remained after the charge was fired. As can be seen, the charge performed very well, breaking the boulder into pieces that could be conveniently handled. In addition, the firing of the charge did not produce any detectable flyrock.

Test 2

The boulder chosen for the second test was similar in shape to that used in the first test but was a little smaller (48 by 22 by 19 inches, 1,800 lb) and was placed flat rather than on edge. The boulder and charge are shown in figure 4.

Since the charge was placed atop the boulder, no tape was necessary to hold it in place. As can be seen in the lower photograph of figure 4, the charge again broke up the boulder well. One large piece remained, but it had so many cracks in it that one blow with a sledge hammer would have shattered it.

Test 3

Because the Bureau's nonincendive charge had performed so well in tests 1 and 2, it was next tested on a much larger boulder (60 by 80 by 48 inches, 20,000 lb). The charge and boulder are shown in figure 5. The charge was not able to shatter the boulder. However, the charge did produce many cracks in the boulder and widened the cracks that were initially present. It appeared that firing another charge against the boulder would have shattered it.

Test 4

Test 4 was conducted to determine whether two of the nonincendive charges fired simultaneously could satisfactorily break a very large boulder similar to that in test 3. The boulder chosen was 91 inches long, 74 inches wide, and 44 inches thick with an estimated weight of 25,000 pounds. The boulder and placement of the two nonincendive charges can be seen in the upper photograph of figure 6. The two charges, placed several feet apart on two flat faces, were fired simultaneously; the boulder was broken into several large pieces and many smaller pieces. The larger pieces were too large to conveniently handle manually, but inspection revealed that they were cracked to such an extent that it would have been a simple matter to break them with a sledge hammer.

As noted for the incendivity tests, no significant flying debris was observed in any of the four tests.

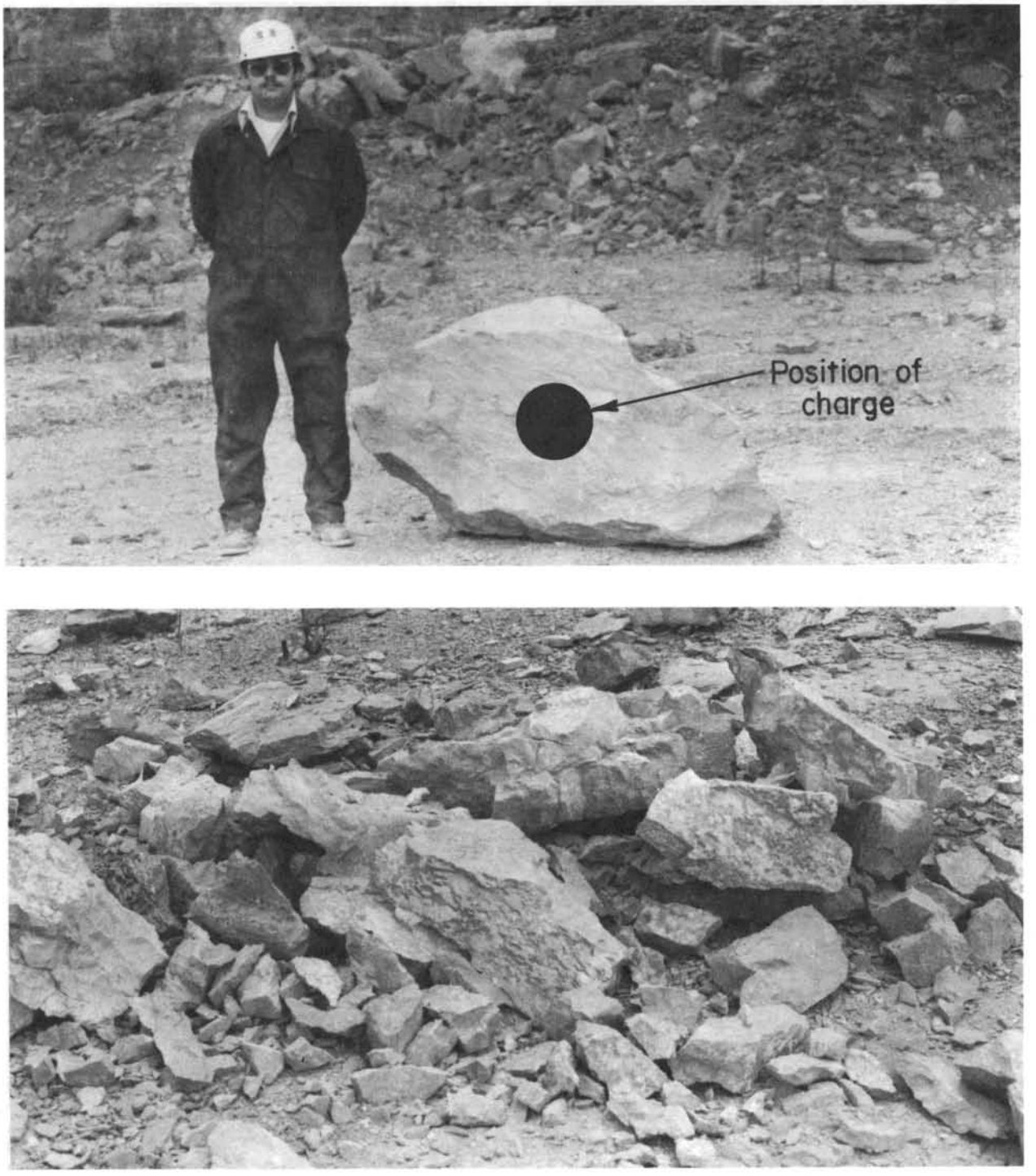

FIGURE 3. - Limestone boulder broken in test 1. Top: Boulder with positioning of nonincendive rock-breaker charge illustrated. Bottom: Remains of boulder after firing the charge.

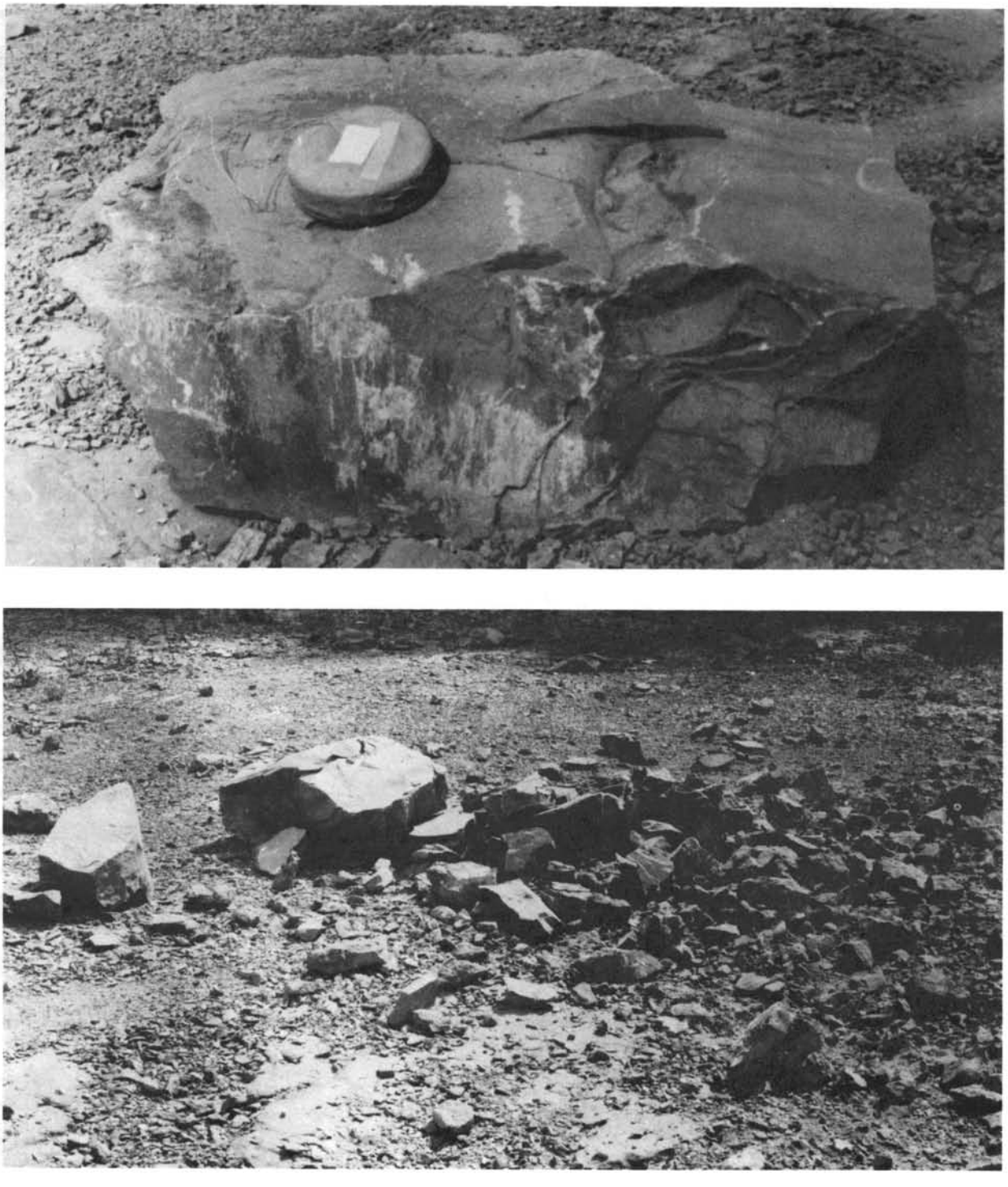

FIGURE 4. - Limestone boulder broken in test 2. Top: Boulder with nonincendive rock-breaker charge in place. Bottom: Remains of boulder after firing the charge.

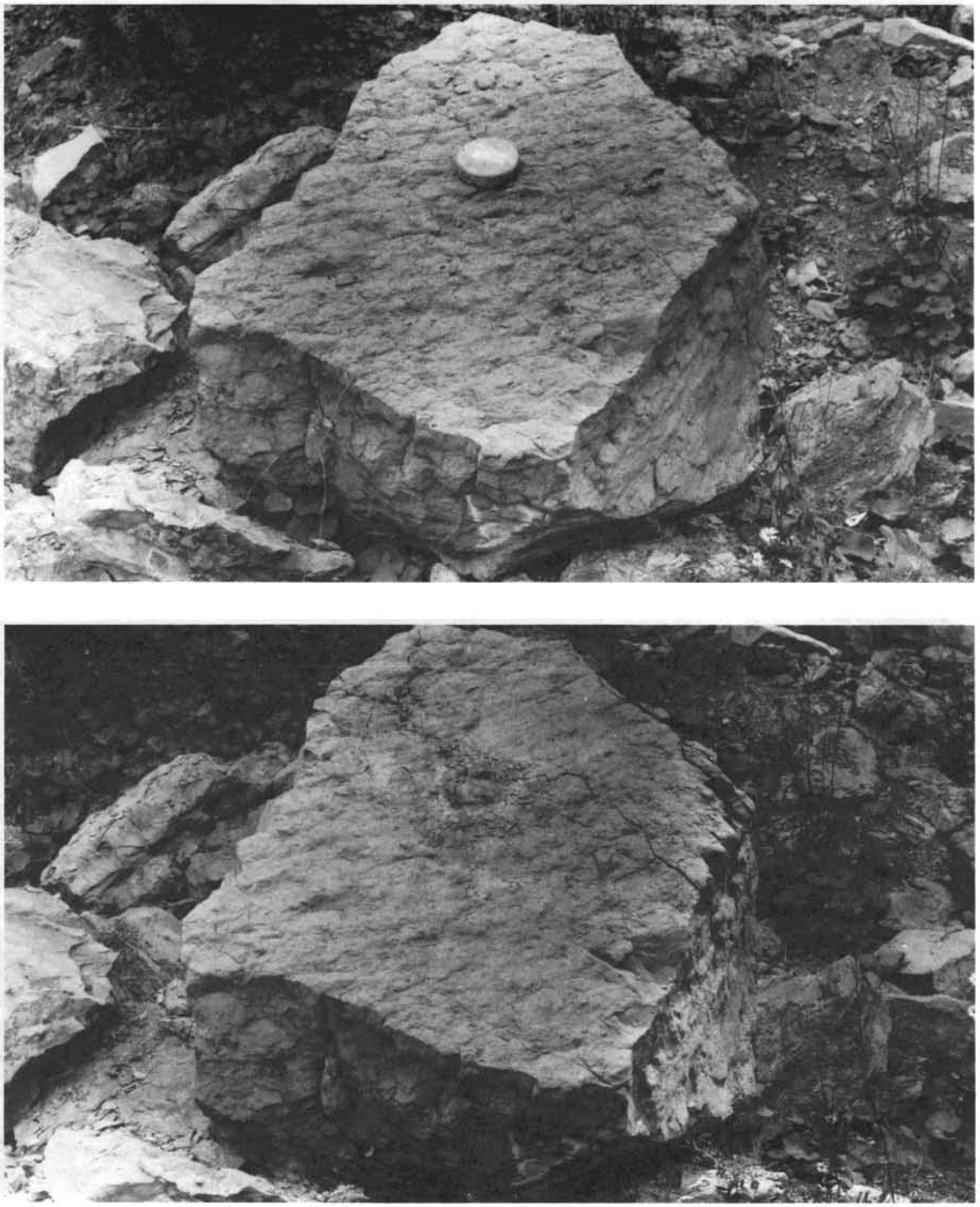

FIGURE 5. - Limestone boulder fractured in test 3. Top: Boulder with nonincendive rock-breaker charge in place. Bottom: Boulder following firing of the charge. This boulder was much larger than the charge was designed to break, yet the charge succeeded in cracking it.

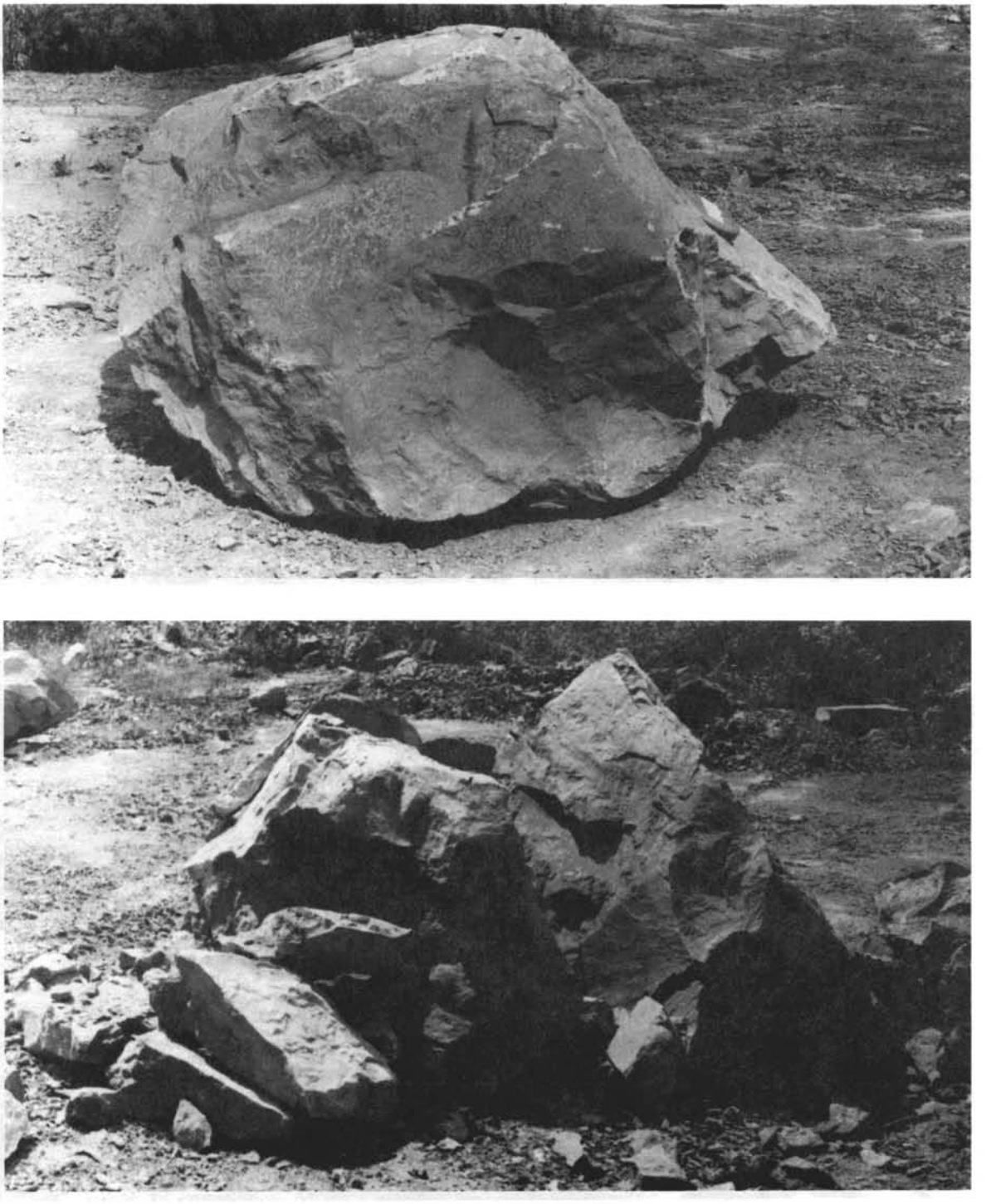

FIGURE 6. - Limestone boulder broken in test 4. Top: Boulder with two nonincendive rock-breaker charges in place. Bottom: Remains of the boulder after firing the charges.

CONCLUSIONS

Preliminary testing of the Bureau's nonincendive rock-breaker charge suggests that it is both safe and effective. It appears that the charge will not ignite a flammable methane-air atmosphere and is capable of breaking boulders weighing up to 2 tons into pieces that can be handled by one person. For boulders weighing up to 10 tons, several of the charges fired simultaneously might be effective. The charges also did not produce a flyrock hazard.

The research reported here represents only a preliminary study of the nonincendive charge. Further questions must be answered before the charge could be approved for mine use, the most important being the question of incendivity. The charge proved nonincendive in 10 gallery tests, but more extensive testing must be conducted to verify its safety in both gassy and dusty atmospheres. Furthermore, incendivity testing must be conducted to determine whether it is safe to fire multiple charges instantaneously or with delays in a flammable atmosphere.

The question of the effectiveness of the nonincendive charge is secondary to safety but is still important. The charge appears to be very effective for breaking 1- to 2-ton limestone boulders, but it may be too powerful for smaller boulders and is ineffective for larger ones. Therefore, it is necessary to develop and test charges of different sizes and further study the effectiveness of multiple charges fired instantaneously and with delays.

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