Blasting to Open Ramelli Pit

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This article is about a blast that was used to open Ramelli Pit. The site is located west of Doyle, California in the Plumas National Forest and is situated on a basalt knoll on the west side of the valley extending northwesterly from Frenchman Lake. The owner, the US Forest Service, did not want the pit to be visible from the road that ran through the valley. This meant designing a blast that would break out approximately 29,000 yd^3 of in-place rock, yet hold short of breaking through the east side of the knoll. The client requested my assistance, but wanted to use equipment he had on hand and to use explosives and detonators with which his people were familiar. He wished to drill 3" diameter holes on a 6' x 6' square pattern and use electric initiation. After asking how much buffer zone I needed to preserve the east skyline of the knoll, he laid out the general site plan. The blast zone was roughly 140' wide (up to 24 holes) and 225' long (37 rows), with the protective buffer zone on the east end and a pad for his crushing/screening plant on the west end. Holes were mostly 36' deep, tapering off to 12' at the west end. It took a fair amount of time to drill the 820 holes and I visited the site several times during drilling to look for signs of mud seams and to make sure that they were not drilling through the bottom of the basalt flow. I had them drill an occasional hole one steel deeper to check for bottom. They would then back fill that hole to the requisite depth.

The 6 x 6 pattern resulted in a powder factor of almost 1.6 lbs per yd^3 which I thought was a bit excessive for basalt. I would have leaned toward a 6 x 8, 7 x 7 or maybe even a 7 x 8 pattern, but the client indicated that he'd rather spend a little more on blasting than on crushing and I couldn't argue with that, although diced and columnar basalt (some call it "hero rock" for what it does for your reputation) breaks out rather well.

The client didn't want me to heave much rock onto his pad for the crushing plant, and because of the need to leave the east skyline of the knoll intact, I had to design a sinking cut blast. I started with an opening cut of 44 holes detonated on Zero delay that would move rock upward and form some relief into which the balance of the holes could break. I skipped the 1st delay to provide a bit more time for that. The surrounding 2nd and 3rd delay holes were top and bottom primed in the event their powder columns were cut off by the opening holes detonating. Since I preferred bottom initiation throughout, the top detonators in the 2nd delay holes were number 3s and the top detonators in the 3rd delay holes were number 4s. Hopefully, these top detonators would be set off by the column detonating from below rather than initiating the top themselves. Delays through 17 were then used to initiate the remaining holes. A diagram of the timing sequence is depicted in Figure 1. Some delays occupied two rows. Others only one. Note that, with two minor exceptions, there are no square corners in the rows of delays. This is consistent with good blast design in that it allows the rock to break out more easily from the corners.

Today, one would use a non-electric or other sophisticated initiation system for such a shot, but the client's desire to use standard electric caps meant that I would have to make sure that all 933 of them (actual count) fired reliably. No power lines were available as a source of power. I did have a VME-450 capacitive discharge (CD) blasting machine. Depending upon whose specs you read, it was rated at either 1000 or 1200 caps for a series-in-parallel circuit. These ratings were based on caps of 2.0 to 2.5 ohms resistance each.

The 24’ and 40’ Hercules Millidets that we were going to use were 2.95 ohms each. Obviously, careful circuit design was needed.

A considerable amount of rock would be thrown straight up in the air. For safety, the blaster firing the shot would be behind a huge pine tree (with no dead limbs overhead) about 750 feet from the shot. To reduce resistance in the blasting circuit, rather than use a couple of standard 14/2 firing lines, I opted to use two 750 ft lengths of 10 gauge solid copper wire as a firing line. To assure that all series saw the same current, I used a reverse series-in-parallel circuit that utilized 12 gauge bare aluminum buss wires, strung on top of powder carton lids, one on each side of the shot. This wiring scheme is depicted in Figure 2.

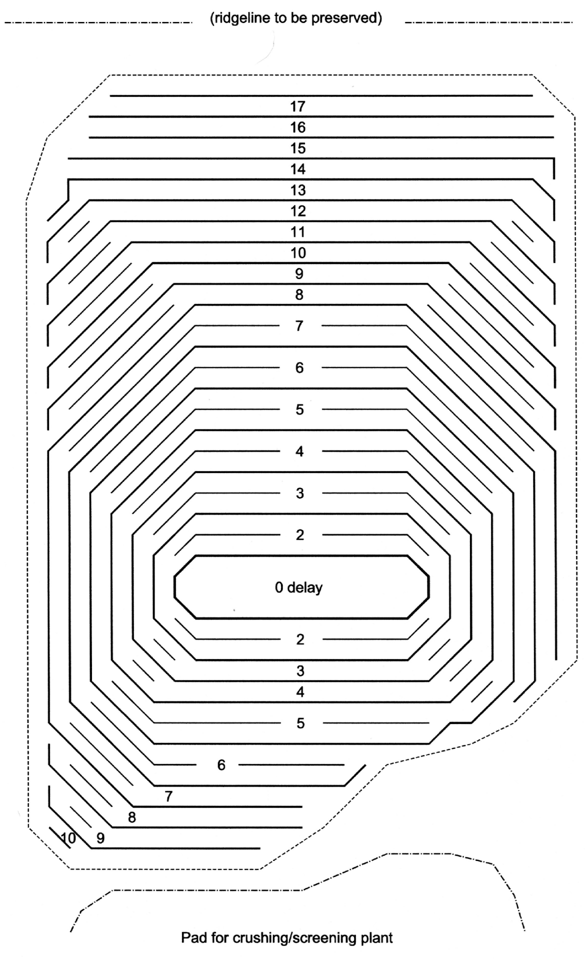

Figure 1 - Rameli Pit Timing Scheme

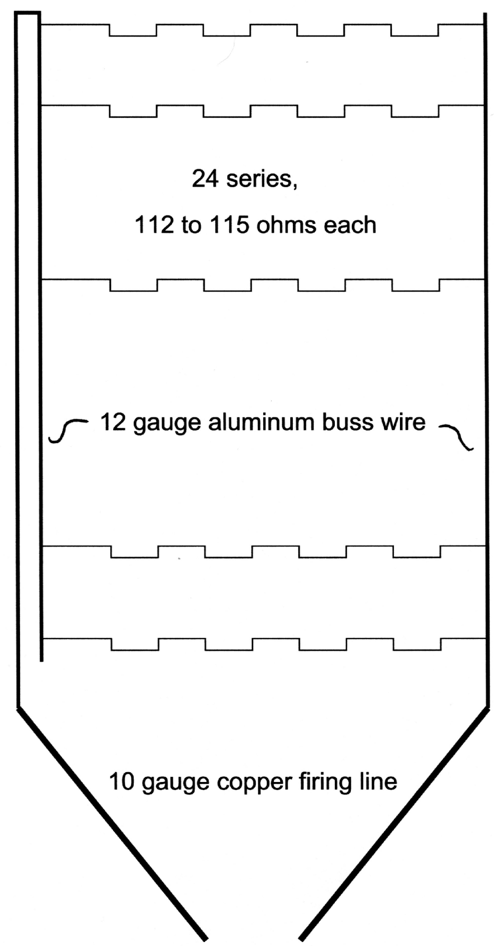

Figure 2 - Ramelli Pit Wiring Scheme

If a 440 volt power line had been available to fire this blast, one could use Ohm’s Law to calculate the current flow through each circuit and divide the series accordingly to obtain the optimum current. When using a CD blasting machine however, the voltage (and current) decays exponentially as the capacitors discharge so that, at some point, the available current falls below that which will reliably shoot a series of detonators. To determine available energy, it was conventional at the time to use the average energy that a CD blasting machine could supply within the first .005 seconds.

I won't go into the actual calculations for determining what the CD blasting machine's available energy was because it requires rather complex math using the machine's voltage, capacitor size and internal resistance, if any, and the total blasting circuit resistance. We now use blasting systems that eliminate the modern blaster's need to do such mental gymnastics. If you really want to know how it was calculated, contact me and I'll send you the numbers and the methods involved. In actuality, most blasters who used electric initiation shot somewhat smaller blasts and just stayed well within the capabilities of their respective CD machines, keeping the number of series smaller than the number of caps in a series, mostly balancing each series, and letting it rip. Most CD blasting machines were powerful enough and had enough built-in safety factor to keep blasters out of trouble. But then again, there have been a few exceptions.... If you approach the limits, you better know what you are doing.

After calculating the current levels for various configurations, I decided to divide the shot into 24 series; 21 series of 39 caps and 3 series of 38. In a reverse series-in-parallel circuit, this resulted in a total detonator circuit resistance of 4.77 ohms. The total blast circuit resistance was then the sum of the following:

The above detonator circuit -	4.77 ohms
plus 2 x 750' #10 copper firing lines @ 1.0 ohm/1000' -	1.50 ohms
plus 2 x 225' #12 aluminum buss wire @ 2.61 ohms/1000' -	1.17 ohms *
Total blasting circuit resistance -	7.44 ohms

* In a reverse series-in-parallel circuit, only 1/2 of the buss wire is used in the resistance calculations because the voltage path through any individual series only passes through half the buss wire. To this, I added one extra 225' length of buss wire to go from the firing line to the far end on one side, all of which counted. This resulted in the total of 450' used in the calculations.

A good VME-450 CD blasting machine with fresh batteries will produce an average of 46 amps through a 7.44 ohm blasting circuit (for the first .005 second). The 46 amps was divided across the 24 series pretty much equally, resulting in a current flow through each series of 1.91 amps. I considered this sufficient current to reliably detonate the entire shot.

It's interesting to note that, had we used 14 gauge duplex firing line instead of 10 gauge, the total blasting circuit resistance would have increased to approximately 9.7 ohms, reducing the current flow into the blasting circuit to about 37 amps. This would have only provided about 1.5 amps per series, which would have been marginal and may not have been enough to reliably detonate all the holes.

We knew it would take more than one day to load the shot. Early on the morning of the first day, Alpha Explosives delivered the detonators, 18 cases of Hercules Gelaprime F and 30,500 lbs of AN/FO. The client brought in 32 cases of Unigel 2 x 16 and 7500 lbs of AN/FO from his stock. I had several loading teams, each with a licensed blaster. I went ahead of them laying out the detonators according to my plan. When we ran out of powder in the afternoon, I picked up the unused detonators and marked those holes with spray-painted numbers so that I'd know exactly where to start again in the morning. (Good idea, right? That night it snowed 2" and covered all my numbers....) We left the shot for the night under the watchful eyes of one of the client's employees. The next morning, Alpha delivered another 10,000 lbs of AN/FO. With the help of the sun melting the snow, I eventually figured out where I was cap-wise and we continued the loading process. After we finished loading, the client sent the remaining detonators and powder back to his magazines.

I then started marking the various series so that a couple of the more experienced blasters could begin hooking them up. Hercules Millidets had one green and one yellow leg wire. In wiring, I had the blasters carry the yellow wire forward to the next hole because it was easier to see on the ground. For the double primed holes, I had them connect both in and out to the yellow wires and connect the two caps' green wires together at the hole to assure that both caps were wired into the series. As they completed each series, the blasters carefully measured its resistance with a blaster's multimeter and then connected it to the shunted buss lines. We couldn't afford to have any series vary much in resistance or it would take more or less than its allotted amperage and could possibly result in one or more mis-fired series.   Those series with double-primed holes required inserting a small amount of connecting wire to reach from the end of the series to one of the buss wires, but that extra wire was offset by the shortened leg wires on some of the caps in the series. As I had anticipated, the last series came up a few holes short, so we added 3 caps to increase its resistance and balance the circuit.   After un-shunting the buss lines and connecting them to the firing lines, we verified the total blast circuit resistance with a blaster's multimeter and proceeded to clear the area.

(A blaster's multimeter was used in place of a blaster's galvanometer because you can't read the scale on an analog galvanometer accurately enough and, with a large series-in-parallel blasting circuit, it was extremely important that we balance each series carefully so that the firing current would be divided accurately across each series.)

After the area had been cleared and checked and guards posted on the access road, we proceeded to a safe viewing site about 2000 feet away. The proper signals were given, the blaster took up his position behind the large pine and detonated the shot. The rock behaved as predicted. Rock from the opening holes shot just about straight up, which started making room for successive rows that pulled away from the side and back walls. (It took a little while for the rock from the opening holes to come down though.) The overall swell in the middle of the shot was approximately 70 feet above original ground. Before and after photos are contained in photos 3 through 8. Unfortunately cloud cover shaded some of these. We were quite happy with the results.

 Photo 3 - Blast zone is gray area. Pad is on this end, just beyond trees. Valley is just beyond shot..	 Photo 4 - Opening holes and the next two or three delays have detonated.
 Photo 5 - The dust is clearing and the amount of swell is becoming apparent.	 Photo 6 - The east wall where the ridge line has been preserved. Fragmentation is typical for entire shot.
 Photo 7 - Southwest corner as viewed from on top of the muck pile.	 Photo 8 - Looking down on the crushing/screening plant pad. The smoke is from the residue of empty cartons and sacks that had been burned. (and, yes, we did throw a little rock onto the pad.....)