Other Methods of Breaking Rock

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Tags: drilling, electron beam, explosive, flame jet cut, lasers, plasma, ream, rock cutting, rock saw, subterrene, tech talk [list all tags]

I thought that this week we would expand the horizon of these talks a little, and talk about the general philosophy of breaking rock, since the extraction of fossil fuel requires more than just the drilling of holes. I'm going to give a couple of further examples of the benefits of breaking rock out into big bits, and then I'll describe some of the more exotic methods that have been tried.

For those who are just passing through, on Sundays I post on some technical aspect of the extraction of fossil fuels, so that those of us that are concerned about their future declining production can understand some of the issues that are involved in extraction. One can find a list of recent posts by clicking on "Tech Talk" at the top of the Oil Drum entry screen, or by clicking on this link tech talk. The last post was on Energy Costs in Drilling, which was meant to leave you with the conclusion that the bigger (in general) you can break the rock out in pieces, then the more efficient it will be. So let me give a couple of examples of this. The first is in mining blocks of limestone in Indiana, and the second quarrying granite (perhaps for Paradise) in Sardinia.

In both cases there is a market for the large pieces that are produced, and thus the alternate advantages of just drilling lots of holes, partially filling them with explosive, and then breaking the rock out into a lot of small pieces is offset by the sales price of the end product. So say you wanted to mine these large pieces, you could take an extra-large chain saw, and cut a set of horizontal slices into the face of the rock at the end of the tunnel.

Rock saw used for slotting rock. It can turn either vertical as here, or horizontal and can have metal teeth (as this one) or small pads of diamond grit set along the chain – depending on the rock it is cutting.

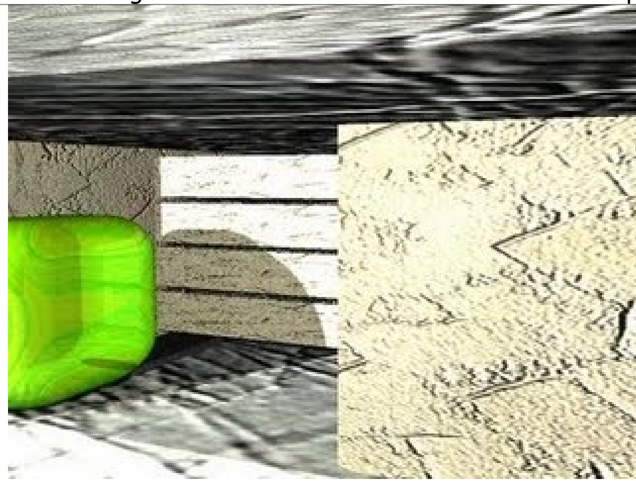


Illustration of underground limestone slab cutting the saw (green) has just cut slots at the top bottom, and at three intermediate levels in the limestone ahead of it. (Rendered in Strata 3D)

Once the slots are made then an air bag is placed in the top slot and inflated, it applies pressure over the full slab surface, so that the force on the top slab is enough to break it loose and it drops on the one below it. Under the shock load this also collapses down onto the one beneath, and so on, until all four slabs sit, one on the other. The can then be dragged out of the mine, and cut into shape, perhaps for replacement parts for Washington Cathedral.

An alternate approach that is used in surface granite quarrying is to drill a series of long vertical holes parallel to one another and perhaps 3 ft back from the face of the quarry wall. These are perhaps 4.5 ft apart, and might be drilled down some 30 ft. The holes are then filled with black powder (less powerful than conventional blasting dynamite) and simultaneously fired. The blast runs a crack along the back of the slab outlined by the drill holes, and then the powder has enough power to tilt that slab over so that it falls into the open quarry. There are two thoughts on what it falls on. Some quarries let it fall on the solid rock, on the idea that if there are weakness planes in the granite then it is good to know this early – others drop the slab onto a mound of dirt, in order not to break it into pieces, and thus get more useful rock out of the slab.

More often, however, when we are breaking rock we aren't concerned so much with the condition of the rock after we remove it, we just want to get it out of the way, either so that we can take it somewhere else to process, or to leave the space so that it can be used for something else (such as a subway tunnel).

Some years ago the National Science Foundation funded a program that looked at a variety of possible new ways to drill through rock. They funded a number of different concepts through a trial, and this gave us some measurements of the relative energy cost and practicality. While I don't have time to go through these in any detail, I thought I might put up a picture and a short comment about some of them. Essentially, as [Bill Maurer showed] some years ago rock can be broken either by thermal means, mechanical fracture or by applying a variety of chemicals. Starting therefore with thermal, there are three different ways to do this: spalling the rock, melting the rock, or vaporizing the rock. Thermal lances have been used to cut the initial trenches in granite quarries for decades.

Hand-held flame jet cutting a slot in granite. Note the slot width and the flame at the bottom of the lance. (These can cut about 14 sq. ft/hour of slot)

This technique is quite loud (over 140 db) since the flame at the end is the equivalent of a small jet engine burning kerosene and air to heat the rock to over 1400 deg C. The flame heats the rock to a temperature where the quartz changes phase, and rapidly expands, breaking off very small chips (as mentioned in the Energy Costs in Drilling post) which can also become airborne and thus a possible respirable hazard.

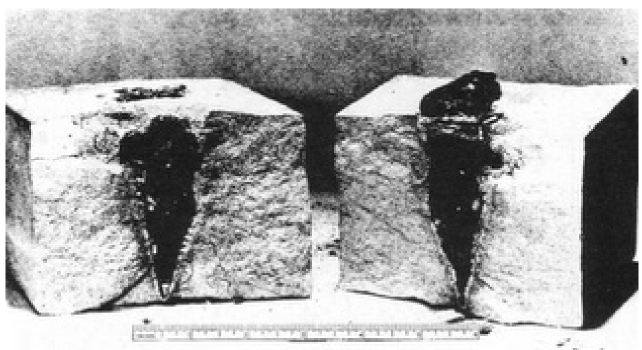
Cloud of fine particles created when a jet burner cuts a slot into a granite block.

If you were using this to drive a tunnel then you would likely need to wear a substantial amount of protective equipment.

Now you can put more energy into the rock, so that it doesn't spall (and some won't any way) but putting more energy in does make a change. In the first case you have molten rock to deal with. A number of folk have looked at that, using different sources as a way of generating the heat. Techniques have included using electric arcs and a plasma.

Cut into rock using a plasma to melt the rock ([US Bureau of Mines])

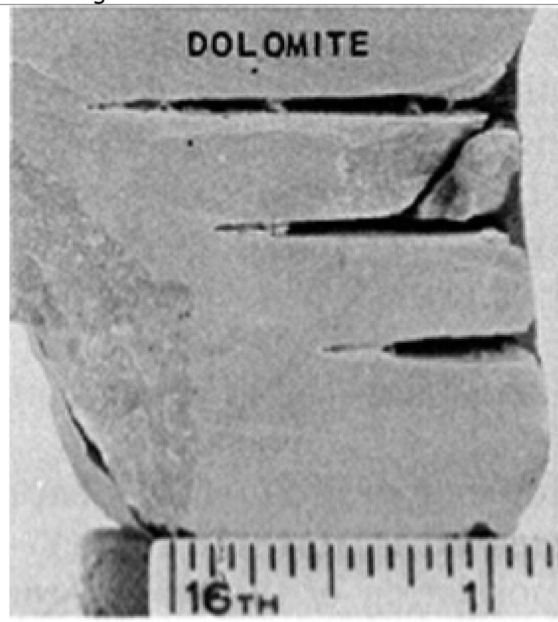
If that wasn't powerful enough there were several further steps that were tried – the first was electron beams (this was a GE favorite)



Cut into rock using electron beams ([Schumacher])

Of course electron beams also generate other things, and apart from dealing with molten rock, dealing with those other issues would have made a tunneling machine that was about 360 ft long. So while it got a glance it did not get an embrace.

Lasers were also tried – they have a little problem of access (although later we thought to use a waterjet as a wave guide) through the mud and while they could vaporize the water in a crack, thereby breaking off quite large chunks of rock, in what is more of a mechanical application, they were also tried to see if they could spall, melt or vaporize rock where they were less efficient.



Laser cuts into dolomite using a 5 kw laser (Carstens & Brown)

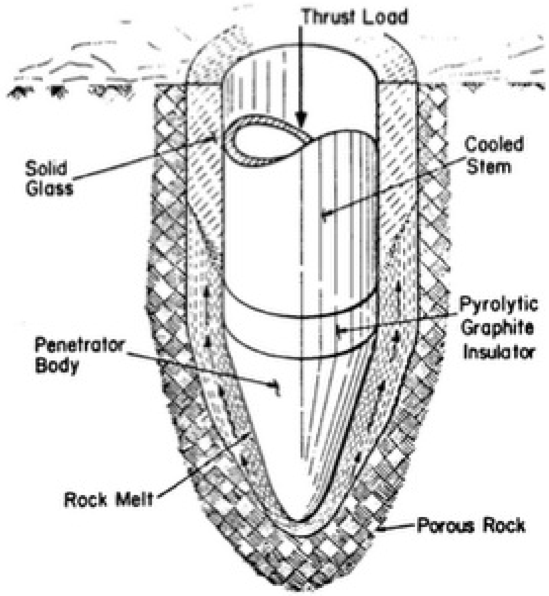
Although this is still receiving some interest there is a problem with all the techniques that I have mentioned so far that require heat, and that is the amount of energy that they have to use to cut the rock.

We measure the energy that is put into the rock to make a hole in joules, and the volume of rock removed in cubic cm (cc) – If you give a skilled miner a pick and a coal face, he can pull off lumps of coal with a specific energy of around 4 joules/cc. (But they will be rather large). A conventional tri-cone type of rock drill can drill at somewhere around 120 joules/cc, so where do these fit?

Plasma jet – between 133,000 and 220,000 joules/cc
Electron beams – 2,980 to 15,700 joules/cc
Laser beams – from 1,600 to 4,820 joules/cc

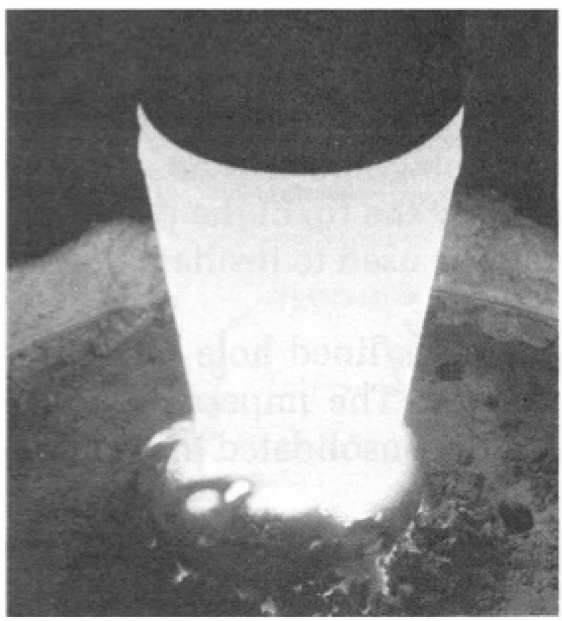
Now it is true that all these tests were in harder rock (granites and basalts) than conventional drills normally penetrate, but I can still show you techniques that in even those rocks keep the numbers down by keeping the fragment size up. But before I get around to mechanical fragmentation let me add one more thermal tool, that has an advantage that might overcome the previous problems in such a way as to justify use.

This was the Subterrene, invented at Los Alamos, so naturally it was powered by a small nuclear reactor. The power from the reactor is fed to a ceramic tip on the drill, which melts the rock ahead of it, and then (this is the clever bit) the molten rock is squeezed into the surrounding rock by the thrust of the bit as it keeps moving forward.

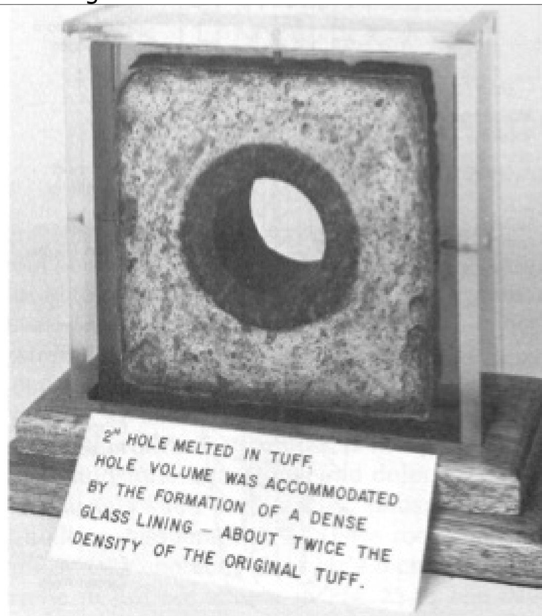


Subterrene drill (LASL)

Now you might be a little cynical about this but a) here is a hole punched through a rock with the technique:



Subterrene melting through – but conventionally not nuclear powered.



Resulting hole drilled by the Subterrene.

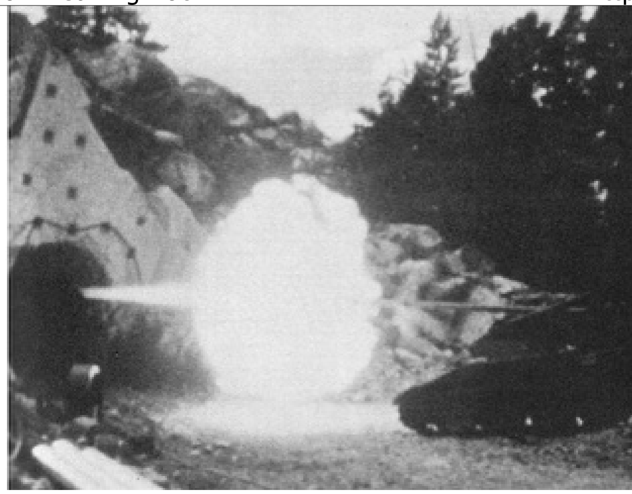
And b) the irritating thing is that I remember that the conventional tool was used to run some underground pipes for one of the local pueblos, with the refrozen rock providing the impermeable liner that was required for the pipe. I thought that it was written up in National Geographic – but alas I can't find the references that I once had. Nor could other folk, because when we tried to get information about it for a possible use in drilling on Mars, a lot of the original information seemed to have been lost over the years.

Going on to mechanical and chemical means, you can drill and drive tunnels using explosives but no conventional drilling – you use the explosive to drive small holes ahead of the face that are the location of the next round:

Hole drilled with explosive but no drill.

Dr George Clark actually drove one of our drifts at the Experimental Mine (that later became the WOMBAT hole) using this idea, and got the tunnel in about four rounds or so.

But the one that I want to finish with is this:



Yes! That is a portable howitzer firing a round to drive a tunnel (REAM after Lundquist)

And for all those who are amused – it did actually drive quite a deep tunnel, and quite efficiently (energy wise) – though there were some issues we don't need to cover in regard to how best to use it. The tunnel was in granodiorite, and as you can see, was of quite a decent size.

Well those are some of the ideas that were tried in the past. Lasers haven't gone away, nor have waterjet drills (of which I may write more in the future). But on a slow Sunday, perhaps this indicates that we really have tried to find other ways of drilling, and that it isn't quite as easy to find something better than ol' man Hughes bit (but there are some things that are!)

As usual this has, of necessity, been a simplified review of what was a rather complex series of tests by some highly intelligent folk. If I have been a little glib in the summary I trust they will either forgive me or comment.