

HYDRAULIC MINING FROM CALIFORNIA TO BRITISH COLUMBIA THE LONG WAY

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Abstract: The use of streams of water to remove minerals in a controlled fashion has been known for millennia. However it has only been in the last 150 years that the tool has found a wider industrial application. The paper traces some of the highlights of the technical developments as the tool moved from a simple nozzle on the end of a rawhide hose being used to mine gold in California, to the sophisticated, remotely controlled machine that mined 3,000 tons of coal a shift from an underground mine in Canada.

Introduction

Water has long been used as an extraction tool in the Mining Industry. Records dating back to the fourth millennium B.C. (Wilkinson 1874, 137) indicate that the Ancient Egyptians used a water separation of gold, the principles of this process being set out in stele to be found in the British Museum. Further one might argue that the legend of the Golden Fleece suggests that the Greeks might well have stolen the lining from the flumes of an early Turkish hydraulicking operation, as they hung drying in a local tree.

In Egypt, however, the water was used for the mineral processing, and it was not until the time of Pliny (Natural History 33, 21) that we find reliable reference to the use of water as a mining agent. The archeological sites that he described in working condition, can still be visited at Las Medulas in Spain (Sanchez-Palencia et al. 1996, 146; also Bird, this publication). Water power in those operations, and in the later "hushing" in the North of England, depended on the natural force of gravity to power the water, and used significant volumes to extract or expose the valuable mineral.

Confining the water to a controllable stream that could be projected through the air was likely first developed in the gold mines of California in the 1850s. There is some controversy (Greenland 2001) over the actual inventor, although much of the contemporary reporting gave Edward Matthison the credit. In 1852, Edward D. Matthison (1823-1903) was almost buried, when the bank he was sluicing fell in. He apparently then sought a technique that would allow him to stand back from the working area. He appears to have joined with a hydraulic engineer named Chabot and changed the system so that water was first collected in a nail keg at the top of the 9 m high bank of weak sandy rock. Water was then fed through a 12 m length of 100 mm diameter, rawhide hose that Chabot built. To the end of this he fitted a trumpet shaped sheet brass nozzle, approximately 90 cm long and 4 cm in diameter, fitted inside in a wooden jacket. This initial test took place in February 1852 at the American Hill Mine near Nevada City (Anon 1857).

By the time of the public demonstration of the technology in June 1853, written up in the Alta California paper (Anon 1853), they had switched to a canvas hose and a solid metal nozzle, made by a blacksmith named Miller. Some indication of the productivity of the system can be indicated by the fact that they were, at 75 cents/miner's inch of water, paying a water bill of \$153.00 a week. The operation nevertheless yielded the four partners of the program \$50.00 a day in profit.

Those early users had found, perhaps unwittingly at first, a technology which is only now being partially exploited (Summers, Whither Water Power, this volume), although it retains its potential. That potential comes from the way in which a waterjet works. In contrast to conventional mechanical cutting

the jet penetrates into the cracks and crevices of the rock, causing them to grow (Summers 1968). In the gold-bearing sandstones of the Sierras this meant that the rock would be disaggregated into its constituent grains as it was mined. As a result the gold particles, being heavy, would easily settle into the flumes. Unfortunately the fine clay particles would not, but rather remained in suspension until the water reached the slow moving Sacramento River, where they settled into the river bed, slowly filling it. This led to flooding and ultimately an injunction from Judge Sawyer in 1883, which largely halted the practice on the scale at which it had previously been practiced (Kallenberger 1970). By that time, however, the benefits of the method had been noted, and it had spread, not only to other States in America, but also abroad to Europe and Asia, as a means, not only of mining gold, but also other minerals.

The low cost and simplicity of the method made it also useful for moving large volumes of ground. It was used, for example, to remove alluvium from the Pacific entrance to the Panama Canal (May 1970) and in developing the Moscow Canal. With the passage of time reliance was shifted from gravity to small mechanical pumps to power the jet streams and I recollect, from a forgotten source, seeing a drawing of an elephant carrying a small pump to a mining operation in Burma as a means of mining rubies.

Mechanically powered hydraulic mining of fuel began in the late nineteenth century in the peat bogs around the Pentane works in Central Prussia (D.S.I.R. 1923) where the peat was flushed into iron channels and carried away by the hydraulic current. This method was further developed by the German Government during the first World War, at the end of which it was also being developed by the new Soviet Government.

Owing to the inability of the Soviet Industry to manufacture equipment capable of withstanding pressures greater than 500 psi, the use of hydraulicking was restricted to the mining of peat and the removal of overburden until 1935 (Siderov et al. 1962, 16-18), when Dr. V.S. Muchnik of the Leningrad Mining Institute was given permission, following his treatise (Muchnik 1952) on the small manpower required to operate a hydraulic mine, to begin trials with the system in the Kizelovski Basin. Following the favourable results which came from this initial trial, where with pressures of 28 - 30 atmospheres, outputs of up to 23 tons per unit were obtained, a hydraulic mine was established in the Donets Basin in the Ural Mountains, in which the coal was to be both mined and transported by hydraulic means (Moynihan 1956).

The development of the system was hindered by the outbreak of World War II, and it was not until 1952 that production began commercially, at the Tyrganskies Uklony hydraulic mine in the Kuznetsk Basin. Output was initially planned to be 500 tons per shift, at pressures around 40 atmospheres water pressure, but by

the end of the year output was up to 600 tons (six times the local average obtained by conventional means) with a recovery rate of nearly 90% (Muchnik 1956). One of the major benefits of this use is that the monitor (the nozzle and swivel assembly on the end of the supply pipe) could be mounted in a drift at the bottom of a seam section and directed upward. It would then wash the coal down into the underlying passage without the need for anyone to enter the working area. By working the panel in retreat the method had obvious potential benefits.

Although it did not prove possible to maintain this high level of output (Sokolov et al. 1964), the results were sufficiently good for a second mine to be converted to hydraulicking, the Polysayevskaya Severnaya, converted in 1953 and producing by 1954. Until 1957 the coal was blasted down from the face by conventional means and washed away by high pressure jets, but in this year it was completely hydraulicised and coal was excavated hydraulically. Further mines were opened after the efficiency of the method has been proved, and the Five Year Plan, 1956-60 (Ignatov 1960) indicated that there were 69 underground units scheduled with a total output rising from 250,000 metric tons in 1955 to 12.5 million tons in 1960. By the end of this period however, some of the disadvantages of the system were beginning to appear and at the Pioner hydraulic mine in the Donets Basin, where output was planned be 900,000 tons per annum, the daily output by 1963 was still only 1,500 tons (Shapolalov et al. 1964). Similar difficulties were experienced elsewhere, but in the 1964 review, plans were to raise the output much higher and mines of output up to 3 million tons were forecast, giving productions of over 12.5 million tons in anthracite alone (Kuz'mich 1964).

Far from Russia, the New Zealand States Mining Department reported the use of hydraulics in the clearing of overburden and the extraction of coal in 1891 (Cook 1953), the coal then being carried in flumes to the consumer. But it was not until 1920 (Cook 1920) that the method became popular, when it was realised that the fluming of coal through the hills was much cheaper than the driving of roads. Hydraulic transport rapidly became very popular and, in 1927, at Cardiff Bridge Mine, water was carried into the mine in an effort to extract pillars left in the waste, and also to transport the coal out of the mine. In subsequent years several other mining companies in the region also used this method of working otherwise unrecoverable panels of coal, since the coal left in the waste was broken by roof pressure and thus easily washed away by low pressure jets

Not until 1947 (Watson 1958) was mechanical power used to drive the jet, until that time the head produced by leading the water from local streams and lakes underground had proved sufficient. In this year the Happy Valley Mining Company installed an underground reservoir and pump and, working at pressures of about 0.6 MPa, raised the output per manshift to 60 tons. The small size of the mines and the low manpower working them prohibited the size of workings that require the large pressures and distribution systems of the European mines. At one mine in New Zealand it was reported that the face would be drilled and shot by the men on the day shift, after which they connected up the pipelines, turned on the water supplied by a stream at the surface, and left the mine. By the next morning the coal has been washed into the flumes, the waste has collapsed and the face was ready for a fresh start (Cook 1957).

British interest in hydraulic mining was stimulated by a visit of a Technical mission to study Russian Mining methods in 1956 (NCB, The Coal Industry in the USSR). Following the report of the mission, the N.C.B. inaugurated two programmes of research, the first was at the Central Engineering Establishment at Bretby (NCB 1960) where investigations were made using differing nozzle shapes and determining their effect in cutting into rock and coal. At the same time various sites were

investigated for suitability for field operations, Trelewis Drift in No. 4 Area, South Western Division being finally chosen. Trials were carried out over the period June 1959 to September 1960 (Jenkins 1964), with investigations being made into differing patterns of extraction and the necessary pre-requisites for hydraulic mining. Estimated potential outputs of up to 61 tons per manshift were established before the tests were completed.

After this field trial the work was passed to the SMRE at Sheffield where investigations were carried out into the jet effect on harder rocks at higher pressures (Leach and Walker 1966). Pulses of water at pressures of up to 5,000 atmospheres drilled to depths of up to 85 mm. in sandstone and 15 mm. in granite. It is appropriate to note that one of the early results of that study was a comparison of nozzle designs for use at high pressure. The conclusion that the Leach and Walker reached on optimum nozzle shape has become the foundation for nozzles used in the broad gamut of industries that now use high-pressure waterjets (Summers, Wither Water Power, this publication). The SMRE team subsequently looked at the use of waterjets as a means of improving the performance of ploughs (Moodie 1976) (following research in the US described below) but the relatively flat seams of the UK and the declining market for coal, together with the development of the jet-assisted picks of roadheaders moved research and application away from hydraulic coal mining by the mid-1970s.

The first underground use of hydraulic mining in the United States was in the Gilsonite mines of Utah in 1948, using pressures of around 12 MPa (Anon 1856). Research showed that the method was practical for mining Gilsonite, providing it could be properly dewatered after mining. Gilsonite is a solid hydrocarbon which cannot be worked conventionally due to the high risk from the highly combustible dust raised. When the dewatering problem had been solved work on a full commercial basis began at Green River Mine in 1956, where, using pressures of around 17 MPa, outputs of 30 tons per manshift were obtained (Argal 1957).

In 1958 the National Bureau of Mines sent a team of observers to this mine and also to the British sites. As a result of these visits and a survey of current progress in the field (Boyd 1959) the Bureau began its own investigations. The equipment required for the gently dipping American seams was developed (Wallace et al. 1961) and then used in the field (Buch 1965; Price and Badda 1965). In these tests outputs of up to 1.6 tons per minute were achieved working at pressures of around 280 atmospheres. Research was then concentrated at the Twin Cities Research Center in Minneapolis (Information from Director of the Bureau of Mines, 1965) and at a site near West Lebanon in Pennsylvania (Fowkes and Wallace 1968), where the jets were used to mine anthracite in a relatively horizontal seam. The work in the steeply dipping seam did not prove fruitful, since the Bureau used a large chock-mounted lance that was too heavy to easily move rather than carrying out the remote mining techniques that had been successful elsewhere.

Experiments in the US took a different turn, following a pair of mine disasters in the early 1970s caused by ignitions of methane. The Bureau of Mines funded three test programs examining different pressure regimes for mining coal. The first was at the University of Missouri-Rolla, in which jet pressures of 70 MPa were placed along the edge of a coal plow (Summers et al. 1974), the second at IITRI in Chicago examined pressures of 300 Mpa (Labus and Silks 1976), using the waterjets to replace the cutter teeth on a continuous mining machine, while Bendix Research Labs examined ways to use pressures of almost 500 Mpa (Rea et al. 1974). Because of the greater effectiveness of jets at lower (though still high) pressure but greater flow volume the UMR device was carried through prototype development in the US (Barker and Summers 1981),

while a German group carried out an underground trial of their version of the system (Schwartz et al. 1981), which was also successful. Unfortunately the disappearing market for such equipment stalled further development.

It was that remote use aspect of the technology that gave it its greatest success. The work in Russia had led to its adoption in China in 1956, where prior to the devastating earthquake of 1977, some seventeen million tons of coal were mined each year (Wang 1983). Production rates of up to 600,000 tonnes per year could be achieved in 1-8 m thick seams dipping at 10° to 30°. However, in contrast to the work in most other countries the monitors in China were more frequently operated by hand with single units producing on the order of 200 tons/hour (Lin 1979). With time, however, pressure increased, although it has only been since 1975 that jet pressures over 20 bar have been used. Innovative technology at these higher pressures, in which the nozzle is oscillated perpendicular to the motion, have led the Chinese to be able to successfully drive headings with the tool (Cheng et al. 1989).

Recognizing the success of the Chinese program Mitsui Mining first began to mine coal hydraulically in the Hokkaido at the Noborikawa mine. As with the Chinese work they had considerable benefit for use where the seams contained high levels of methane (Wakabayashi 1979). By 1978 the mine was producing around 700,000 tons from the hydraulic section. As with the original Russian concept the mine was developed with slightly rising drifts working out from the shaft and set at intervals of around 15 m down the seam section. By successively mining the drifts down dip, but pulling each one back in sequence behind the one above successful extraction of the otherwise difficult to mine coal was achieved.

Although many other countries have studied the technology and developed variants on the themes outlined above, the only really outstanding success that hydraulic mining found in the West was in the Sparwood mine owned by Kaiser Resources at Crow's nest in British Columbia. The mine was operated from 1969 until the early 1980s and after obtaining a licence initially for the Russian technology, was able to significantly improve it and automate the process. Entries were driven at 5° up-dip on a spacing of 15 m. The coal was around 15 m high and the drifts were some 3.6 m high. The entries were driven using a roadheader which dumped the coal into the flume being laid along the side of the entry thus using water to take away even the earliest mined material from the section, and heavily supported. The mining machine, a monitor mounted on the front of a small crusher, was dragged up to the back of the entry, and located 15 m from the end. The supports over this length were then removed and the mining began. Typically the monitor used a pressure of 120 bar at the pump, at a flow rate of 5,250 lpm through the 31.7 mm diameter nozzle. A flow straightener was used within the nozzle to shorten the effective length required to produce a jet that would mine coal as far as 30 m. from the nozzle.

The operator stood at the back of the crusher, some 12 m from the monitor, and listened to the sound as he steered the monitor back and forward over the roof, slowly inclining in back along the passage away from the unit. He used sound to detect the moment when the jets broke through to the overlying drift, and then moved the jet slightly forward to mine the next pass. In this way almost all the coal in the seam was washed down into the entry, where it fed through the crusher, and into a plastic lined flume where the water and gravity carried it, initially out of the mine, but in a later years to a shaft for pumping out (Parkes and Fisher 1983). Over the years that the mine was in operation the two-men crew averaged a production rate of 3,000 tons/shift with a maximum of around 4,000 tons in the six-hour period. In its time it was the safest mine in Canada.

Regrettably the number of places where this technique can be successful are limited and, although there have been a number of attempts around the world to resurrect the technology again, it is now, once more a sleeping giant¹ waiting to awake.

Notes

1. This is an attempt at a feeble pun, given that the earliest monitors were known as "Giants" in California.

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