Recovery of Minerales Monclova Minas V

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ABSTRACT

Methane issuing from a roof-bolt hole ignited when the hot bit was withdrawn. Similar ignitions have occurred in other mines. This one differed in that flames spread quickly, coal was ignited, and, after three futile hours of applying inadequate water and extinguishing agents, the mine was sealed.

Fires are fuel and ventilation controlled. In this mine there was an abundance of methane, coal, and wood lagging. Recovery of the mine, therefore, depended on successful control of its ventilation. The recovery was done without anyone suffering a scratch; a remarkable feat considering the abnormal methane outflows and concentrations, the continuing evidence of on-going thermal reactions, and what once were inexperienced but now amongst the best mine rescuemen.

KEYWORDS

Explosion, Fire, Rescue, Methane, Oxygen Centration, Ignition, and Mine Recovery

INTRODUCTION

Minas V is one of six mines in and around Palua, Mexico, owned by AHMSA, the largest steel producer and mine operator in Mexico. Palau, in the desert in the eastern foothills of the Sierra Madre, is best reached by a 5-hour drive south of San Antonio, Texas as shown in Figure 1 at the end of this paper.

Minas V is key to the future of the Palau district; it was the company's primary reserve for high-quality metallurgical coal.

The mine (Figure 1) was opened by two slopes, one the main intake, the other a combined belt entry with a man-supply hoist. The fan on the shaft to the right of the slopes was a Joy M-96-50- 1200. The 7-entry mains (C. Gral Sur) had been driven 300 meters from the slope bottom. No. 1 Oriente, the future tailgate, was 530 meters long; No. 2 Oriente, the future headgate, had been driven 450 meters. (Figure 2 at the end of this paper).

The fire began at the face of the number 3 entry in the C. Gral Sur. Within three hours it spread to the Nos. 1 and 5 entries and into No. 2 Oriente. The miners withdrew; and, the shaft and portals were sealed.

THE FIRE

The following summarizes key actions leading to the recovery of Minerales Monclova Mina V (MMMV). Where appropriate, the why's and wherefore's of those actions are discussed.

11 May – The General Manager, Ing. Lorenzo Uscanga and Carl Pelastro[(1)] called detailing the fire in and sealing of Minerales Monclova Mina V (MMMV).

15 May – Ing. Uscanga and the Safety Director, Armando Diaz, came to Birmingham, AL. Among the critical actions discussed were where boreholes would have to be drilled, other key mine-atmosphere sampling

points, sampling procedures, and the need to train and equip Minas V and Micare[2] miners

6 June – Stevenson and Mitchell went to MMMV, examined the site, and discussed conditions and possible actions with Don McBride[3], management, and engineers. We detailed the mine-atmosphere sampling techniques and procedures we wanted; and, finalized arrangements to have syringe gas samples sent to Precision Gas Testing's Brookwood, Alabama laboratory pending transfer of their equipment to MMMV.

14 June – A preliminary mine recovery plan was sent to MMMV for review and comments.

In its preparation, we were of the opinion that recovery was contingent on having:

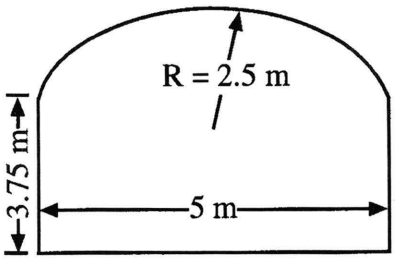
1. At least six, well-trained and well-equipped mine rescue teams with benchmen and fresh-air basemen[4].
2. On-site, 24-hour/day analysis of atmospheres from specific locations within the mine.
3. Oxygen concentrations maintained below 2%; and,
4. Positive trends in the ratios CO/CO_2 and H_2/CH_4.

That plan was based on the air-lock method of recovery. This method was needed to militate against reignition of smoldering coals and wood with the high probability for igniting methane. It also was essential for optimizing the recovery of the inclines, particularly with the potential for lightening strikes igniting methane in the mine[5].

22 June-3 July – The Illinois Department of Natural Resources, informed us that Don McBride had to return to his Benton, Illinois post. Following intensive interviews of persons with the proven experience and competence to continue McBride's work, we recommended that MMMV hire Patrick Graham[6].

17 July – Ing. Uscanga and Minas V Manager, Jose Franco met with us to discuss the status of the recovery and their concerns with the plan. Prior to this, we had discussed the plan with mine-rescue people in the United States, all of whom had many years experience in mine-fire fighting and mine recovery. Without exception, they were concerned with the safety of even the most experienced mine-rescue teams while traveling down, air-locking, and reventilating the inclines and shaft bottom given:

1. The 3 to 5 inches of water gage methane-induced pressure on the incline and shaft seals; and,
2. The essentiality of constructing better-than-good seals by teams wearing self-contained breathing apparatus while working on ladders in their efforts to seal the irregular roof and cavities above lagged arches in ~16°, wet, slippery, ~920-meter-long inclines having a cross-section like this:



19 July – The new recovery plan was based on flooding the area in which fire might have propagated and in which rekindling was highly probable. The rationale for this is discussed later.

27-28 July – Mitchell went to the mine to review the mine-rescue team training, and to discuss the flooding option with mine engineers and management.

1 August – The final draft-recovery plan was submitted based on the previous discussions at the mine and again with experienced mine-rescue people in the United States. It detailed:

Phase I: Injecting water through Borehole 2 to the 104-elevation "shoreline"[7]. Its goals were to:

a) Quench on-going thermal reactions (e.g., smoldering or hot materials);
b) Establish "explosion-proof" seals inby C. 1 Oriente;
c) Have at least 100 inches of water pressure against methane liberation from C. 2 Oriente and the C. Gral Sur entries inby; and,
d) Force chemical reactions[8] that would make us aware of on-going thermal reactions in areas through which water flows, their extent and seriousness, thus aiding in subsequent decisions.

This plan also discussed the efforts needed to recover: 1) Inclines A and B; 2) the Shaft bottom; 3) the Shaft; 4) C. Gral Sur entries to and C. 1 Oriente; and, 5) the remainder of the mine.

In preparing this plan, we knew water might damage the mine roof and bottom. We also knew

that was, at best, a possibility. The probability was that without flooding and without the ability to supplement operations with nitrogen injection, should the need arise, recovery was too dangerous to consider based on our knowledge (really our lack thereof) regarding on-going thermal reactions. We discussed this, as follows, in our note of 18 August to management:

Some Minerales Monclova officials are concerned water might cause serious damage in flooded entries. They pondered whether the shoreline should be lower than the 104-meter (above sea level) given in our 30 July-recovery plan. Their concerns are valid; and, normally, I would agree.

Unfortunately, conditions in Mine Mimosa V are not normal. In fact, the argument could be that a higher level is more appropriate. It was recognition of these conditions that caused us to modify the 19 July-plan. What are or were those conditions?

1. *Hot carbons[9] (probably smoldering coals and, perhaps, wood) reacted with the water being injected during the last week of July and the first week of August. Purportedly, the shoreline during that period was at 95 to 98 m., placing those carbons between Borehole 2 and C. 2 Oriente. This is supported by comparison of the graphs for H_2 from Boreholes 1 and 2 samples, considering the impact of the methane outflows from C. 2 Oriente and the C. Gral Sur faces[10].*
2. *Prior to sealing, temperatures in the Shaft were purportedly 1350°C. It is prudent, therefore, to suspect hot carbons at elevations as high as 107 m. Should oxygen concentrations rise above 12 percent where such hot carbons are present, ignition of the inby as well as surrounding bodies of methane could lead to a series of devastating explosions[11]. The damage from these would likely be the cause for far greater, irrecoverable damage to the mine (e.g., destruction of the Shaft and Inclines as well as entries) than could be caused by flooding.*
3. *Methane liberations from C. 2 Oriente and the C. Gral Sur faces are the major source for the methane-induced pressures against the Incline and Shaft seals. Someone else may, but I do not know how those seals and how debris in those openings can be removed safely unless those pressures are reduced to below that needed to inert the atmospheres immediately inby. It was for that reason I selected bringing the water to the 104-shoreline[12]. As an added bonus, with this shoreline we should have formed "explosion-proof" seals across C. 2 Oriente and the C. Gral Sur faces.*

4-7 September – Final preparations were made to breach the incline seals. Precision Gas Testing's mobile lab was set up at the mine.

7-12 September – With methane-induced pressures almost zero, the B" and later the "'A" Incline seals were breached. The teams traveled to the No. 3 crosscut (X/C). Basically, the procedures involved, first airlocking, and then ventilating.

12 September – Shortly after 1615 hours, fire engulfed the main fan house[14]. The inclines were plugged with dirt. The fire was extinguished by 2330 hours.

15 September – The dirt plugs were removed, and teams explored the remainder of the inclines to the bottom of Tiro Vertical (the main shaft). The accessible C.. Gral Sur entries were sealed; Tiro Vertical was uncovered completing Phase 2.

22 September – With two auxiliary fans blowing into "A", controls were placed in the inclines to ventilate the Shaft bottom and force air up Tiro. This completed Phase 3. The exhaust air flowing from Tiro became a continuous sampling point to monitor gases being liberated from unexplored areas in C. Gral Sur.

25 September – Water was pumped low enough to permit the teams to explore to the faces of C. 1 Oriente. The C. Gral Sur entries inby C. 1 Oriente were sealed. A 72-inch-diameter fan was installed in the mouth of "A" Inclinado in the exhausting configuration. Tiro Vertical was reversed, making it an intake. This completed Phase 4.

Dewatering to bring the "shoreline" to the 100-elevation was begun. This enabled everyone to get a much needed rest, though the teams monitored the mine atmospheres in conjunction with the lowering "shoreline".

13 November – The teams resumed their advance up C. Gral Sur. Our major concerns were the chance of rekindling in the return entries and in the overcasts just inby C. 2 because the source(s) for the increasing CO/CO_2 trend had not be found. To militate against rekindling, advancing airlocks were constructed on the left side of C. Gral Sur and seals were built at the "shoreline" in the other entries. During this, and prior steps, roof was reinforced where necessary; dewatering pumps were brought up to the "shoreline"; and, the fresh-air base was advanced.

17 November – The main fan on Tiro Vertical began exhausting; the fan in the mouth of "A" Inclinado was removed; and, the inclines were again the primary intakes.

24 November through 2 December – The teams advanced C. Gral Sur to C. 2 Oriente, and sealed inby the C. 2 Oriente overcasts. As the teams progressed into and past the third crosscut in C. 2 Oriente evidence of fire faded.. Rock falls prevented further exploration. Fortunately, gases flowing from C. 2 indicated no serious thermal activities were likely in C. 2 (that is, the chance hot materials were inby was negligible).

This completed our work on the recovery of MMMV. As stated at the beginning, this recovery was done without anyone suffering a scratch; a remarkable feat considering the abnormal methane outflows and concentrations, the continu-

ing evidence of on-going thermal reactions, and what once were inexperienced but now amongst the best mine rescuemen.

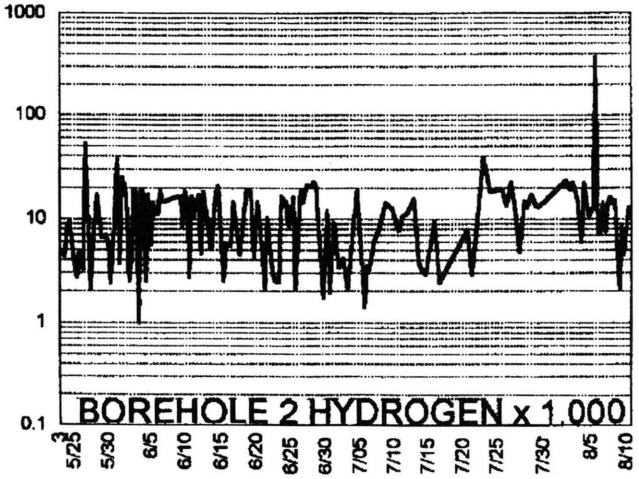
APPENDIX

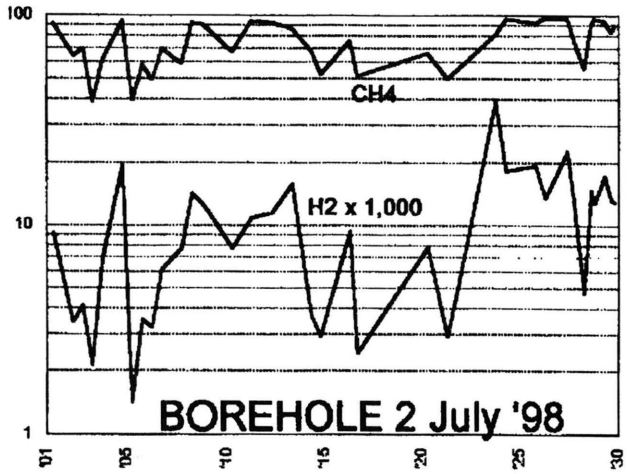
Analysis of Gases

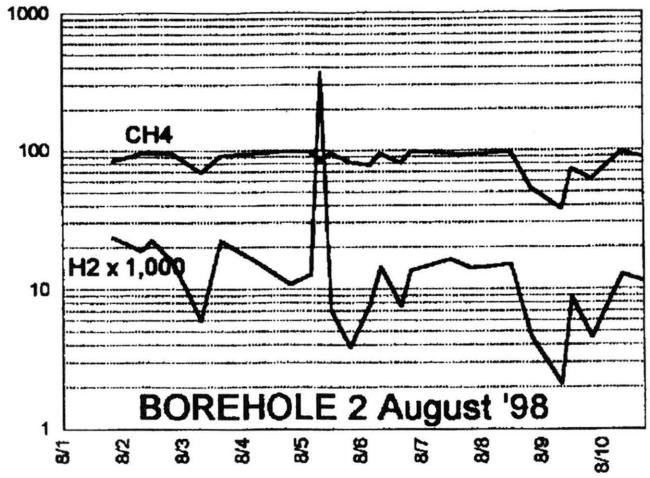
Analysis of the gases sampled in boreholes 1 and 2 indicated:

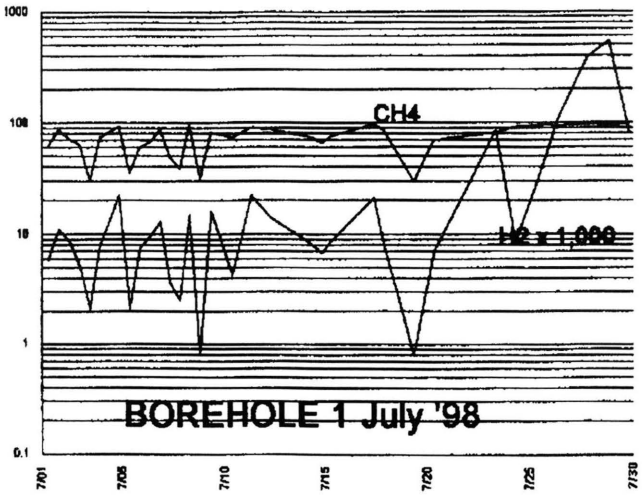
a) Thermal reactions between water and heated carbons occurred between July 23 and August 5.
b) These were outby BH2
c) They had been quenched.
d) We could not determine whether thermal reactions were on-going in other areas. If there were, and the oxygen concentration rose above 12% in their vicinity, an explosion could occur. And,
e) Most important, there was no on-going fire.

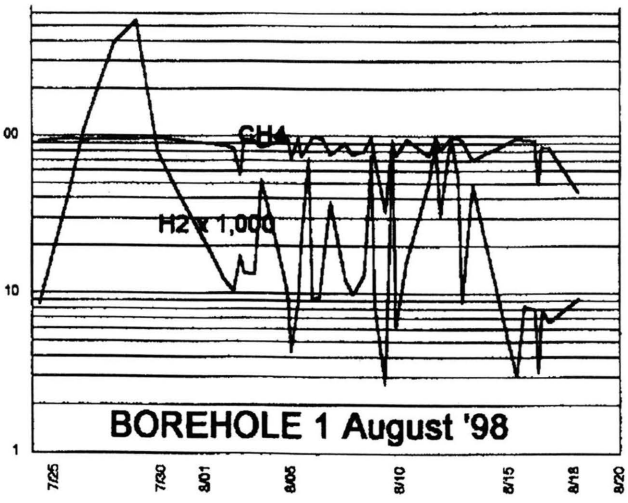
These findings were based on data in graphs such as those that follow. The first five diagrams illustrate definite relationships between methane (CH_4) and hydrogen (H_4).





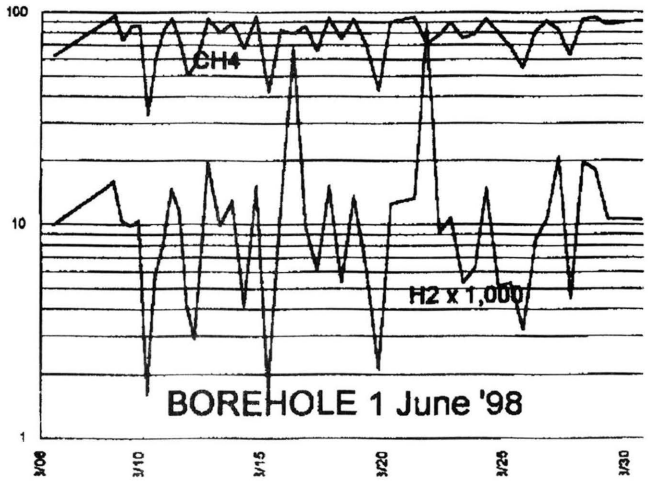


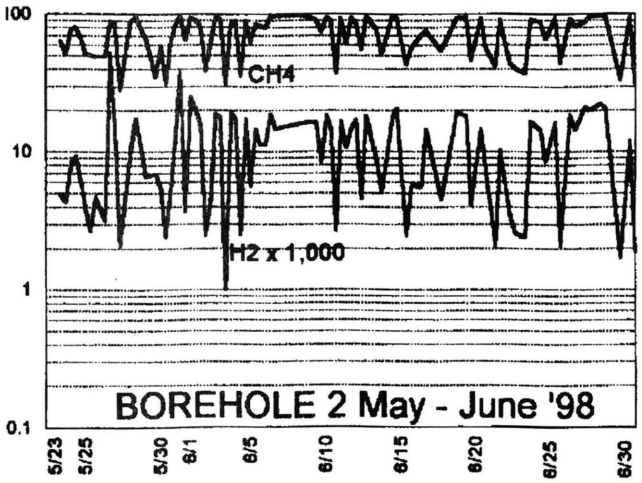




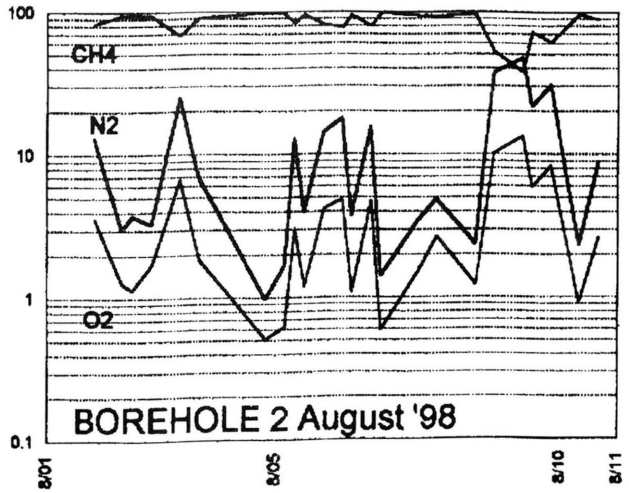
When thermal reactions are not obvious, the curves and trends for one are basically the same as the other. When thermal reactions occur, note, if you will, the hydrogen "eruptions".

This same relationship existed among H_2 and the oxides of carbon (CO and CO_2).





Equally important is the relationship between air (primarily nitrogen and oxygen) and CH_4; that is, when there was an increase in the concentrations of N_2 and O_2 there was a commensurate decrease in CH_4 as shown in the graph that follows.



These N_2-O_2 data showed neither consumption nor absorption of oxygen, clear evidence of no on-going fires despite the presence of heated carbons. While water was being pumped into and later out of the mine, we and mine management carefully followed these trends, watching, in particular, for even the slightest evidence of an abnormal change in the relationships among hydrogen and the other gases or a sustained increase in either the CO/CO_2 or in the N_2/O_2 ratios. Such evidence would lead to immediate reevaluation of what was being done.

Footnotes:

1. Carl Pelastro is a Pacific Corp. engineer and an outstanding mine-rescue person.
2. Open pit mines outside Piedro Negras owned by Minerales Monclova.
3. Don McBride is a senior member of the Office of Mines and Minerals in the Illinois Dept. of Natural Resources. He is also one of the leading mine-rescue persons in the United States. He developed and initiated the mine-rescue training and equipment programs at MMMV.
4. Prior to this, we had lengthy discussions with various people regarding their availability to train mine rescue teams should Illinois officials not permit Don McBride to remain.
5. The ignition of in-mine methane-air bodies by lightening strikes propagating into the mine has become a matter of great concern based on these being the source for explosions in the Mary Lee, Oak Grove, Pinnacle, and Quinland mines.
6. Pat Graham arrived at MMMV on 16 July. By 20 August, he was satisfied with the competence of the benchmen, fresh-air basemen, the Mimosa and Micare team members, and the equipment. Graham, Stevenson, and I are awed by the outstanding work done by those teams. Never, in my 50 years in mine recovery, have I experienced greater dedication than given by them. More important, despite extreme hardships and difficult tasks not even a single scratch was suffered. A detailed report of the training and subsequent recovery operations is available for interested persons.
7. Water might cause damage to the mine roof and bottom. That is a possibility; recovery without the use of water is too dangerous to consider based on our present knowledge or lack thereof regarding on-going thermal reactions.
8. The reaction between a slow flow of water into smoldering carbon-based materials, such as coal and wood, should generate hydrogen (H_2), carbon dioxide (CO_2), and carbon monoxide (CO).
9. Once ignited, coal and wood will continue to issue flames in oxygen concentrations as low as 5%; at lower concentrations - including 0% - they will smolder and even glow until being consumed. The sole advantages of < 5% O_2 are that the hot carbons are not likely to propagate much beyond their location and combustibles such as methane cannot be ignited.
10. This is detailed later in the section Analysis of May - 12 August 1998 Gas Data.
11. Methane (5 - 15% in air) will be ignited by sources hav-

ing temperatures > 5,360°C. Once ignited, flame temperatures will rise to ~1,300°C, and combustible limits will spread to ~0.5 - ~21%. The resulting heat will cause negative as well as positive pressure zones to develop. Should there be a source of air, the air will be drawn into the negative-pressure zones, diluting the methane contained therein, and extending flames with the development of secondary, tertiary, ... explosions. The explosions in the No. 9 Mine (1968, Farmington, WV) were but one of many examples of this.

12. Floor elevations at the mouth of C. 2 Oriente range from 100.73 to 101.06. These openings are purportedly 2.7-m-high.
13. The lab consisted of a computer-controlled Hewlitt-Packard 6890 Gas Chromatograph, two other separate detectors, and support equipment.

The cause for this fire is not known; it was initiated in the fan house.

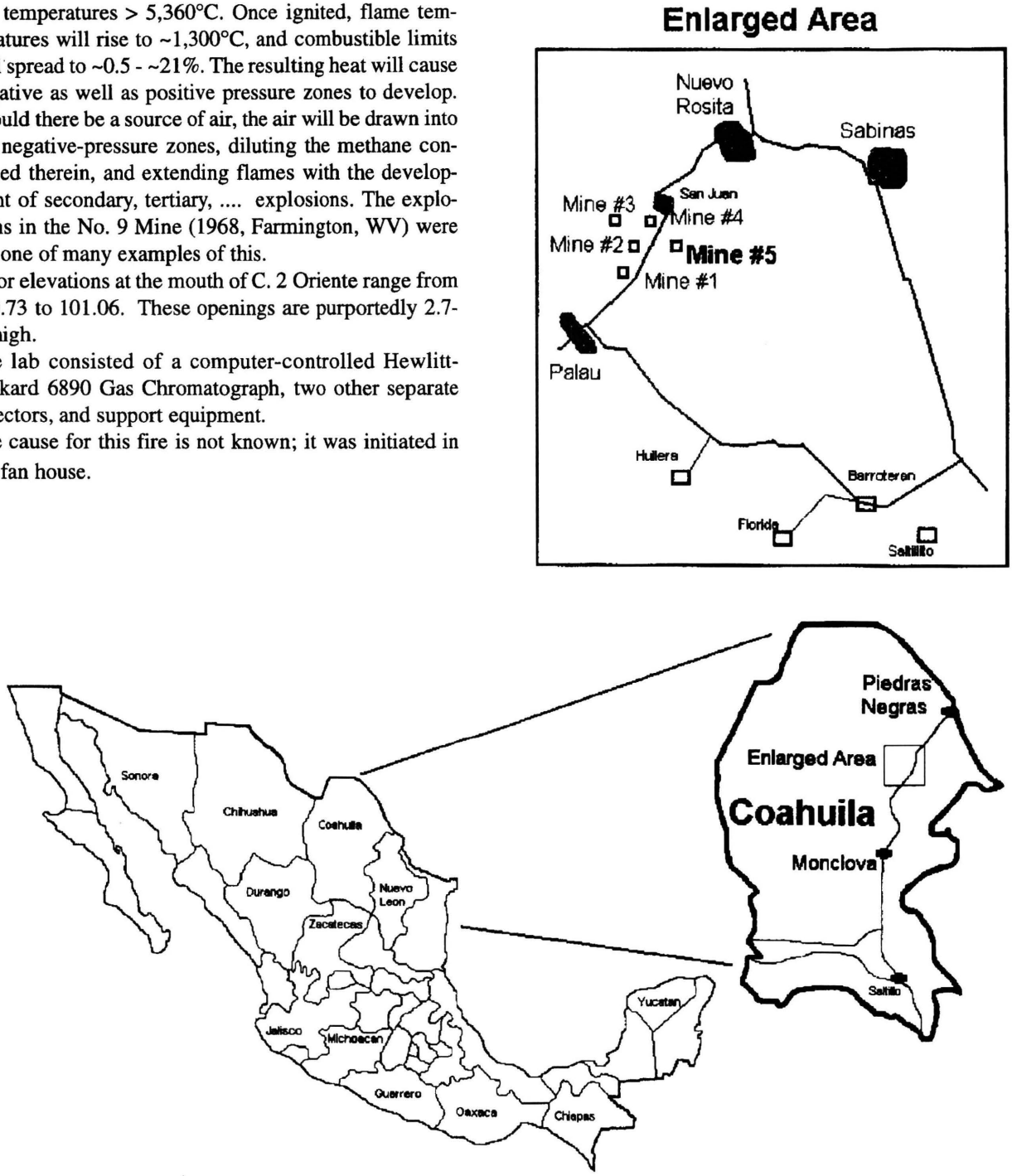


Figure 1. Location of Minerales Monclova Minas V.

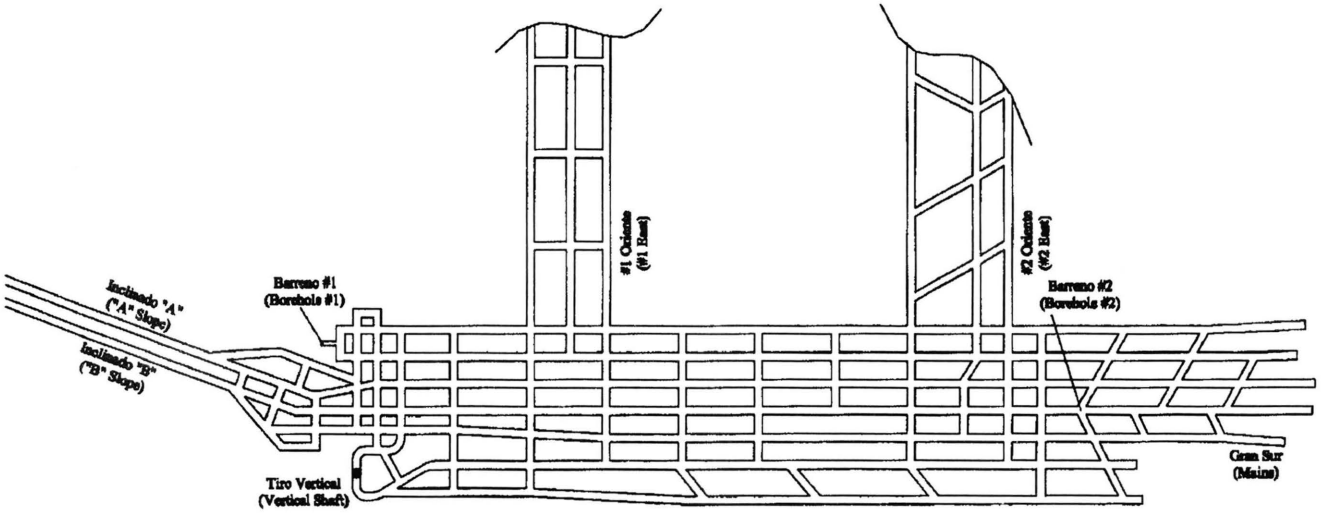


Figure 2. Map and identification of Locations Minerales Monclova Minas Mimosa V.

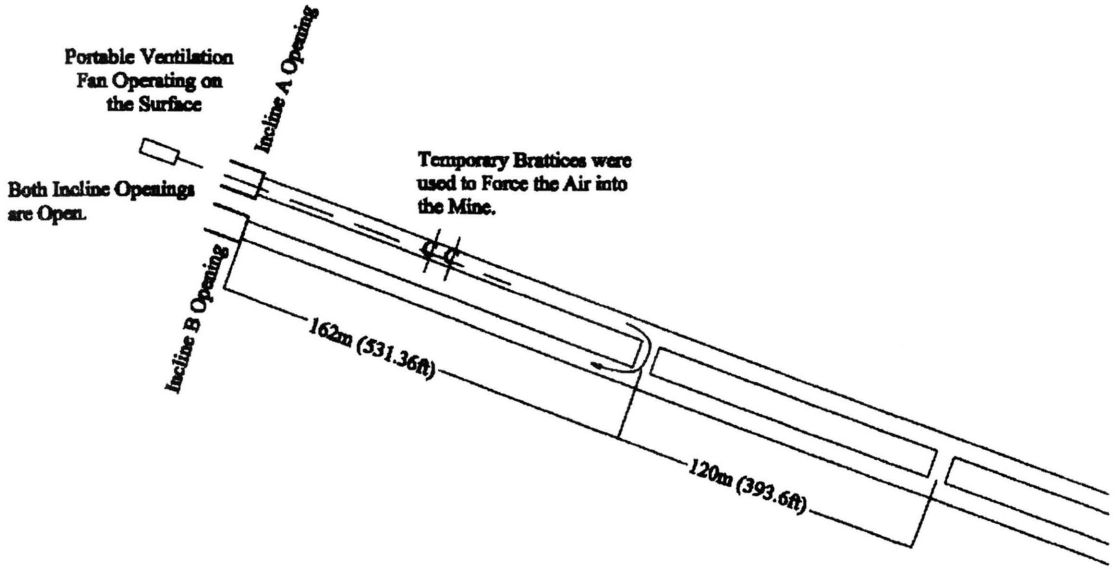


Figure 3. Minerales Monclova Mina Mimosa V - Initial Mine Ventilation.