

OZARK UNDERGROUND LABORATORY

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FINAL REPORT

RESTORATION TECHNIQUES FOR REMOVING UNNATURAL BLACK COATINGS FROM
CAVE SURFACES IN THE SNOWBALL DINING ROOM, MAMMOTH CAVE, MAMMOTH
CAVE NATIONAL PARK, KENTUCKY

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An investigation and report for Mammoth Cave National Park prepared under purchase
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Fronticepiece

Top photo: Snowball Dining Room; photo taken about 1960. The caption on the reverse of the card states that recent developments have expanded and improved this facility. Note that the ceiling is relatively white, but that some grey coatings are already appearing on the ceiling.

Bottom photo: Snowball Dining Room; photo copyright 1977. Note the unnatural black deposits on the ceiling; they are substantially worse now (1986).

Both views are taken looking toward the food serving area. Note the dramatic degradation of the cave surfaces over a period of about 17 years.

This report identifies restoration techniques which we believe will restore the "snowball" appearance to the Snowball Dining Room. We believe it will be possible to restore the chamber to an appearance similar to that in the circa 1960 photograph.

Fronticepiece



Abstract

The Snowball Dining Room within Mammoth Cave owes its name to the delicate gypsum "snowballs" which decorate the ceiling. The natural color of these features was white with a reddish hue.

The beauty of the gypsum snowballs is now concealed beneath a grey to black unnatural coating (see fronticepiece). The coating is unquestionably the result of use and management practices within this chamber.

An extensive laboratory investigation was conducted to find techniques which might remove the unnatural coatings and restore near-natural color and appearance to the Snowball Dining Room. These tests determined that a 5.25% sodium hypochlorite solution would oxidize (and thus destroy) much of the unnatural coatings when lightly sprayed on the cave surfaces. Rinsing with water is an important part of the treatment approach.

This study was envisaged as a two phase investigation. Phase I, which this report details, was designed to identify potentially useful restoration techniques for removing unnatural coatings from cave surfaces in the Snowball Dining Room. Phase II investigations will lead to the actual restoration of the Snowball Dining Room. Phase II investigations will also develop management recommendations for preventing or minimizing future unnatural coatings on cave surfaces in Mammoth Cave.

Executive Summary

Mammoth Cave has experienced many years of visitation by millions of people. The cave was heavily visited by Indians who lighted their way with torches and built fires in the cave. Later visitors used lard oil and kerosene lanterns. Cigarette smoking was permitted in the cave. Food was cooked and kept warm in the Snowball Dining Room. These activities, and others, have put residues and discolorations on natural cave surfaces. These residues have obscured and significantly altered many important cave features.

The most extensive unnatural coatings in Mammoth Cave are in the Snowball Dining Room, and particularly on the ceiling of this chamber. About 60% of the black ceiling surfaces in the Snowball Dining Room are gypsum. The gypsum surfaces beneath the black coatings are crystalline; the texture is highly irregular and the features are very fragile. As a result, the removal of the unnatural coatings cannot be done by scrubbing.

Based upon microscopic observations, it is our finding that the cohesive black material which coats many of the surfaces in the Snowball Dining Room is largely derived from cooking and heating foods. However, food preparation may not be the only important source of the black deposits.

Microscopic observations of some samples from the Snowball Dining Room also disclosed the presence of fungal mycelium. The extent of fungal growth on the gypsum is difficult to quantify; there is no reason to believe that it is only in the form of mycelium. Bacterial growths may also be a component of unnatural wall coatings in the Snowball Dining Room.

During the summer use season in the Snowball Dining Room there are routine (but unnatural) daily increases in both air temperature and relative humidity in the Snowball Dining Room. Temperatures in the Snowball Dining Room typically begin to increase at about 10:00 AM, and will increase noticeably until about 12:30 PM. They then increase more slowly until reaching a peak at about 4:00 PM. Temperatures then decrease at a fairly steady rate until about 7:30 PM when they have returned to about the same temperature as existed prior to 10:00 AM. The mean temperature increase associated with the daily cycles is about 0.9 degrees F.; daily increases vary from 0.5 to 1.5 degrees F.

Relative humidity values in the Snowball Dining Room also show a daily cycle during summer. Relative humidity begins to increase at about 9:45 AM, and increases within 15 minutes to an hour to a new and fairly constant value. The increased relative humidity persists until about 2:30 PM; it then declines until about 4:00 PM when it has returned to about the same value as existed prior to 9:45 AM. The mean increase in relative humidity associated with the daily cycles is 1.5%; increases range from 0.5 to 2.0%.

The almost daily increases in temperature and relative humidity in the Snowball Dining Room reflect use of this chamber. Temperature increases are caused by the

electric lights, cooking and heating elements, and by body heat from visitors and employees. Some temperature increases may also be associated with the introduction of water into and through the restroom facilities. Relative humidity increases are probably due primarily to steam from hot food; human respiration may also be involved.

The routine daily temperature increases are important in transporting grease and other particles upward toward the ceiling in the Snowball Dining Room. At some times increased temperatures and relative humidities in the air of the Snowball Dining Room may be sufficient to cause some condensation on cave surfaces, which in turn may increase the number of particles which become attached to the cave ceiling.

Filtration of large volumes of air disclosed that substantial quantities of black material are suspended in the air of the Snowball Dining Room. This occurs even during times of low visitation. The black material is believed to be primarily carbon compounds.

Variations in the amount of black material found in the air filters suggests that some non-continuous processes are important in introducing the black material into the air or in keeping it suspended in the air. Air velocities through the cave passages could be a very important factor. Similarly, fluctuations in air temperature and relative humidity could be implicated in the introduction of the black material into the air from cave surfaces.

A total of 44 potential cleansing agents were selected for laboratory study. These agents included acids, bases, solvents, reducing agents, oxidizing agents, detergents, sequesterants, surfactants, degreasers, and biocides. The laboratory studies on gypsum samples from the Snowball Dining Room and vicinity indicated the following cleansing potential for various groups of cleansing agents. Oxidizing agents are best; they are better than strong bases, which in turn appear to be substantially better than any other types of agents. Strong bases are better than acids; acids are similar in performance to degreasers and solvents, which in turn are better than surfactants, sequesterants, and detergents. Biocides and reducing agents are the least effective in removing the unnatural black coatings from the gypsum.

A number of the tested cleansing agents have potential problems which would limit or prevent their use in the Snowball Dining Room. Some of the cleansing agents are difficult to remove from the gypsum, some damage the gypsum, some create fumes, and some have general toxicity problems. The potential problems for various products are summarized in Table 6.

Based upon laboratory and field tests, the most promising cleansing agent is 5.25% sodium hypochlorite (bleach). It works by oxidizing (and thus destroying) the unnatural coatings.

Applications of 5.25% sodium hypochlorite solutions are followed by water rinses. Vinegar may be useful in some problem areas. The vinegar dissolves gypsum from the contact between the coating and the underlying natural material.

Our laboratory experiments suggest that about 95% of the unnatural coating on gypsum and limestone surfaces can be removed by a procedure outlined in the section of this report entitled "A Preliminary Cave Restoration Approach". The approach uses 5.25% sodium hypochlorite solutions and water rinses.

Resolving the problem of the unnatural coatings in the Snowball Dining Room was initially viewed as a two phase project. Phase I was to determine if there appeared to be a methodology for removing the unnatural coatings. If Phase I was successful, then Phase II was to put the system into operation.

Our Phase I studies have been completed. They have been extremely successful, and we have found a methodology which offers tremendous potential for the restoration of the Snowball Dining Room as well as other relevant portions of Mammoth Cave.

Phase II investigations should begin and continue through the winter of 1986-1987. The investigations should include the following tasks:

1. A study of potential problems, limitations, and adverse impacts of the restoration techniques.

2. Field testing designed to "work out the bugs" in the recommended techniques. This work would be done during the winter to minimize conflicts with cave visitation. Field testing conducted during Phase I investigations indicated that techniques may need to be adjusted and tailored to different conditions in the cave.

The field tests will be a time for National Park Service personnel to become familiar with the recommended techniques and their applications. Familiarization and training of National Park Service personnel in the recommended techniques is viewed as a necessary and integral part of the work. It is our expectation that the restoration techniques which are developed can be readily used by National Park Service personnel who are likely to be assigned to restoration work.

3. Assessment of all developed portions of Mammoth Cave to determine areas where restoration work is warranted. Unnatural coatings, while most noticeable in the Snowball Dining Room, are not restricted to this portion of the cave.

It is possible that areas can be ranked according to the urgency of restoration work and/or the magnitude of resource restoration which is attainable. Such a ranking would be done if it appears appropriate. Additionally, we would identify modifications of techniques which may be needed for localized situations. Some techniques may need to be excluded from certain areas or situations.

4. Develop management recommendations for preventing or minimizing future development of unnatural coatings on cave surfaces in Mammoth Cave. This would include:

A. Development of a history of use in Mammoth Cave useful in characterizing the nature and extent of activities which may be associated with the unnatural coatings in the cave.

B. Air filter studies to increase understanding of the source and movement of carbon compounds within Mammoth Cave.

C. Identification and evaluation of all use and management activities which appear to be associated with unnatural coatings in Mammoth Cave. Additional investigations of the nature and composition of the coatings as warranted and technically feasible.

D. Development of specific management recommendations.

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Introduction

Mammoth Cave has experienced many years of visitation by millions of people. The cave was heavily visited by Indians who lighted their way with torches and built fires in the cave. Later visitors used lard oil and kerosene lanterns. Cigarette smoking was permitted in the cave. Food was cooked and kept warm in the Snowball Dining Room. These activities, and others, have put residues and discolorations on natural cave surfaces. These residues have obscured and significantly altered many important cave features.

The residues not only obscure cave features and degrade the natural integrity of the cave, but they may also interfere with the future growth of speleothems (cave formations). The residues need to be removed so that the natural qualities of Mammoth Cave can be restored.

The most extensively impacted area in Mammoth Cave is the ceiling of the Snowball Dining Room. The name snowball related to the initial white, gypsum-coated, ceiling of this chamber. The ceiling is now black. The change in ceiling color from white to black apparently began in the late 1950's. It was at this time that an elevator shaft was constructed into this part of the cave. Along with the elevator shaft came a sewage pumping station, a restroom with flush toilets, and an underground dining hall which serves hot food.

About 60% of the black ceiling surfaces in the Snowball Dining Room are gypsum. The gypsum surfaces beneath the black coating are crystalline; the texture is highly irregular and the features are very fragile. The removal of the black coating obviously cannot be done by scrubbing (which is a rather "standard" way of removing dirt).

An appropriate restoration technique (or a series of techniques) for the Snowball Dining Room will have the following four characteristics:

1. The techniques will be practical and feasible for the amount and nature of restoration work necessary.
2. The techniques will be safe for workers and will not unduly interfere with cave visitation.
3. The techniques will not create offsetting damage to any cave features, including cave fauna.
4. The techniques will restore features to near-natural condition. We do not want aesthetic restoration, but instead want restoration to near-natural conditions.

Scope of the Study

This study was designed to determine if there were restoration techniques which potentially could be used for removing the unnatural materials coating cave surfaces in the Snowball Dining Room. The study has been successful and has found appropriate techniques.

Techniques which are successful in the Snowball Dining Room will obviously have applications elsewhere in Mammoth Cave. The unnatural black coatings are unfortunately not limited to the Snowball Dining Room. Our current study has focused on the Snowball Dining Room for two reasons. First, because the problems are extensive and severe in this part of the cave. Secondly, because this segment of the cave has already been extensively modified.

The current study was specifically designed to determine if there were any apparently workable treating agents and/or treating techniques for restoring the natural surfaces in the Snowball Dining Room. As indicated in our study proposal, a supplemental study was anticipated if apparently workable treating agents and treating techniques were discovered. This supplemental study would have the following objectives:

1. Development of detailed procedures and approaches for the cave restoration work.
2. Development of an adequately detailed assessment of any potential adverse impacts which might result from the restoration work. Ways of mitigating any such problems would be identified and discussed.
3. Development of management recommendations for preventing or minimizing future accumulations of the unnatural deposits. Results obtained in the present study clearly indicate that the unnatural black coatings on cave surfaces are currently increasing. The unnatural coatings are related to both past and present management situations and practices. Restoration work alone would address a symptom rather than the basic problem. We must not only restore the natural surfaces, but we must also take management actions to minimize (and to the extent possible prevent) future unnatural deposits. The identification of the needed management actions is a primary objective of a supplemental study.

Literature Review

This study is the first investigation of the unnatural coatings on surfaces in Mammoth Cave. Although cave restoration studies have been conducted in several other caves, none of the prior work in the United States has dealt with materials similar to those coating most cave surfaces in the Snowball Dining Room of Mammoth Cave.

Newboulds (1973) discusses the steam cleaning of Orient Cave in Australia; this is one of the famous Jenolan Caves. As a result of over 50 years of heavy tourist visitation Orient Cave had become heavily discolored by mud, dust, and lint. Several attempts were made to clean the cave with hot water steam and detergent. The early attempts failed because of inadequate steam generators. Finally, after about 7 years of various efforts, a suitable steam generator was found. The cave was then cleaned using a mix of hot water steam and detergent, and then rinsed with clean water. The results were deemed highly successful. However, it appears that the assessment of the results were based upon esthetic considerations only. Newboulds (1973) includes no assessment of any adverse or potentially adverse impacts from the cleaning treatment. In view of the use history of the treated cave it is quite possible that adverse impacts were minor; this is what we would expect.

After the cleaning of Orient Cave it was re-opened to visitation on October 1, 1972. Newboulds (1973) reports: "A final examination of the Orient Cave was made on April 1, 1973. For the six months period, 8,222 persons had visited the cave. An amazing amount of textile fibres was adhering to the wire netting fencework. Mud and grit are covering the track and steps. In areas some mud has been deposited on areas of flowstone beside the track."

Williams (1979) reports on cave cleaning studies in Waitomo Caves, New Zealand (this is the world-famous glow-worm cave). Williams (1979) states: "Every visitor to the caves carries in small dust particles which accumulates along with air borne dust from roads and paths. Residues from the early use of candles, kerosene lamps and magnesium flares are still evident on horizontal ledges in the cave. Experimental cleaning with variable pressure steam jets has produced spectacular results and the planning of a major clean up of Glow-worm Cave has now commenced. The major clean-up will be followed by regular and frequent cleaning of walls and formations. Any cleaning operations have to be consistent with glow-worm ecology and cave fauna in general."

The work by Williams (1979) is of particular interest since some of the residues which were removed in test cleanings were from the early use of candles and kerosene lamps. Some of the unnatural black deposits in Mammoth Cave result (at least in part) from past use of candles and kerosene lamps.

Aley (1972) conducted tests in Blanchard Springs Caverns with hot water steam in an effort to kill plant growth. The surfaces used in the testing were rock and firm calcite speleothem surfaces. Use of steam on these firm surfaces did not cause any detectable damage to substrates (Aley, 1972).

A steam generator was purchased in 1973 for routine use in Blanchard Springs Caverns. The results of its use were reported by Lemon (1976). Major problems developed when hot water and steam were applied to weathered calcite speleothems. The applications caused substantial spalling of the natural crusts which coated the weathered speleothems. Unpublished studies by Tom and Cathy Aley suggested that some of the problem was that application temperatures were not hot enough; workers were applying hot water rather than steam. The plan had been to apply steam. The application of hot water rather than steam resulted in increased treatment time and thus more spalling of delicate speleothem surfaces.

Steam generators, such as routinely used in greenhouses for sterilization of seedbeds and weed control, typically develop nozzle pressures of 0.35 to 0.7 kg/sq.cm. (Aley, 1972). It seems likely that pressures at speleothem surfaces in Blanchard Springs Caverns were less than this since workers were trying to minimize the damage to natural crusts (Lemon, 1976). In view of the field experiences in Blanchard Springs Caverns we conclude that very delicate cave features cannot be cleaned with steam without causing at least some physical breakage of the features. The utility of steam as a cleansing agent is a function of both temperature and pressure. Studies by Newboulds (1973) and Aley (1972) both suggest that very low application pressures will dramatically reduce cleansing performance. However, no authors who have dealt with steam cleaning of caves tested very high temperature ("dry") steam. It is possible that dry steam might provide effective cave cleaning without major physical breakage of very delicate speleothems (such as those in the Snowball Dining Room).

Our literature survey uncovered several other articles on cave restoration. Knutson (1974) suggested scrubbing of calcite formations with water. He further suggested the use of hydrochloric acid where the discoloration cannot be removed by water alone. Frith (1976) recommends spraying graffiti with a 5 to 10% hydrochloric acid solution followed by scrubbing and rinsing with water. Frith (1976) concluded that acid treatment removed about 75% of all cave graffiti; he had no recommendation for removal of the remaining 25% of the defacement.

Plantz (1978) noted that the use of hydrochloric acid in caves produces calcium chloride. He further noted that calcium chloride is a deliquescent agent (it absorbs moisture from the air). Plantz (1978) was concerned about cave cleaning programs which tended to leave calcium chloride on treated features or on adjacent cave floors. It is our conclusion that his concerns would be negated by rinsing treated features and then collecting and removing the rinse water from the cave.

Kerbo and Rohde (1978) describe extensive accumulations of dust and lint on cave surfaces in Carlsbad Caverns. Rohde (1982) documents restoration and cleaning efforts in Carlsbad Caverns. For lint and dust removal brushing and sweeping were attempted, as was rinsing with water. Rohde (1982) found that these treatments were applicable only to smooth floors and flowstone. The methods were not practical in delicate areas decorated with popcorn or aragonite or in areas of dehydrated and decaying calcite or in gypsum areas (Rohde, 1982).

Most of the cave restoration work in the United States to date has involved the control of exotic plant growth. The most detailed discussions are Aley and Aley (1984); Aley and Aley (1985); and Aley, Aley, and Rhodes (1986). The strategy of choice consists of two facets: 1) minimizing the extent of plant growth, and 2) killing plant growth before it becomes well established. The control agent of choice at caves where detailed studies have been conducted is 5.25% sodium hypochlorite (Aley and Aley, 1985).

The present study in Mammoth Cave has found that 5.25% sodium hypochlorite solutions are highly effective in destroying the unnatural coatings in the Snowball Dining Room. Because of this finding, the environmental assessments incorporated in Aley and Aley (1984 and 1985) are particularly important. These assessments indicate that 5.25% sodium hypochlorite solutions, when properly used, do not create significant adverse impacts. Aley and Aley (1984 and 1985) found that this solution did not interfere with subsequent deposition of calcite and aragonite speleothems. They also found that this solution did not alter the colors of any of the tested speleothems.

Studies at Mammoth Cave

The Study Area and its Use

The Snowball Dining Room is located in a natural chamber within Mammoth Cave. The chamber, which is called the Snowball Dining Room, is about 190 feet long and averages about 45 feet wide. Much of the ceiling is relatively flat, and is typically 7 to 8 feet above the floor. The highest ceiling areas in the Snowball Dining Room are in the cooking and serving area where they are about 12 to 15 feet high.

The floor of the Snowball Dining Room has been covered with concrete. There are 51 dining tables in the chamber as well as counters, tables, and other features characteristic of a cafeteria which serves simple, but hot, lunches.

Adjacent to the Snowball Dining Room are restroom facilities with flush toilets and hot air hand driers. Another passage from the Snowball Dining Room leads to an elevator which connects with the surface. Adjacent to the walkway and the elevator is a sewage pumping station which pumps raw sewage from the cave to the surface for treatment and disposal.

The Snowball Dining Room was named for the white and light yellowish brown gypsum which coats about 60 percent of wall and ceiling surfaces in the chamber. The remainder of the surfaces are limestone bedrock which is not coated with the gypsum crust. The natural gypsum crust consists of somewhat translucent crystals; the surface is both irregular and fragile. Many pieces of the gypsum crust have been broken by previous visitors and removed from the cave (presumably for souvenirs). However, the remaining gypsum (were it not coated with the unnatural deposits which are the subject of this study) is extremely beautiful.

Color of Features

The very light color of the cave chamber led to its initial name "Snowball" Dining Room. However, man's impacts have dramatically altered the chamber; the walls and ceilings are now very dark in color. Colors on cave surfaces in the chamber now typically range from dark greyish brown to black.

In order to study colors, one needs to be able to describe them as accurately as possible. We did this by using the Munsell system of colors (Munsell Color Corp., 1975).

The Munsell system is based upon three variables that combine to describe all colors; the values are known as hue, value, and chroma.

The hue notation of a color indicates its relation to red, yellow, green, blue, and purple. The value notation indicates its lightness. The chroma notation indicates its strength (or departure from a neutral of the same lightness).

Under the Munsell system, colors are assigned a standard number and letter

designation as well as a standardized name. As an example, the color of gypsum at Station 28 in the Snowball Dining Room was 10YR 4/2. The standardized name for this color is dark greyish brown. The 10YR refers to the hue. The 4 refers to the value, and the 2 refers to the chroma.

Appendix A is a photocopy of the explanation for determining colors according to the Munsell system. This material is derived from Munsell Color Corp. (1975)

A number of color determinations were made of gypsum in side passages near the Snowball Dining Room. These determinations were designed to characterize natural gypsum colors.

The area in the vicinity of the Upside Down Well was useful for characterizing gypsum colors. The following colors of gypsum were found in that area:

10YR 4/4 (dark yellowish brown).

Slightly dirty gypsum in the same area was 10YR 7/1 (light grey) grading to 10YR 8/1 (white).

Thin gypsum crust on the ceiling was 10YR 6/4 (light yellowish brown).

Gypsum crusts along Specimen Avenue are commonly 10YR 5/1 (grey).

The natural color of the gypsum crust in the vicinity of the Snowball Dining Room is typically near-white, but with a common 10YR hue. There are typically localized areas which have more intense and more saturated colors within the 10YR hue group.

A few colors of non-gypsum surfaces were also determined. Limestone in the vicinity of the Upside Down Well was 10YR 5/2 (greyish brown). Soil along the trail into the Snowball Dining Room was 7.5 YR 5/6 (strong brown). The same soil color was found along the trail in the vicinity of Edison Avenue.

Nature of the Unnatural Coatings

The unnatural coatings on gypsum and limestone surfaces in the Snowball Dining Room are typically grey to black in color. Where the coatings are thin, some of the color of the underlying gypsum or limestone can still be seen. Upon close examination (and especially under magnification) there are numerous soil or dust particles which adhere either to the cave surfaces or to the unnatural coatings on these surfaces. The dust or soil particles typically comprise an estimated 10 to 50% of the foreign materials coating cave surfaces. The dust and soil particles are particularly noticeable on fairly horizontal surfaces, but they are also very noticeable in the numerous pockets and irregularities on gypsum substrates.

Much of the unnatural coating consists of black irregular flecks of material. Some of this material is plate-like, but much of it in the Snowball Dining Room is composed of a fairly cohesive and fairly sticky material. For examination purposes some of the coating was removed from a sample with vinegar. The black flecks were coated with numerous fragments of gypsum and soil particles. Another sample of the black material was removed from gypsum with a surfactant. Again, the black flecks were

coated with numerous fragments of gypsum and soil particles.

Later in this report we will discuss studies of filters through which substantial volumes of cave air were passed. The filters commonly collected substantial amounts of black flecks which appear to carbon compound particles. The particles on the filters are much smaller than the cohesive material recovered from surfaces in the Snowball Dining Room. None of the particles on the filters appear to have any other materials attached to them. It seems likely that only the lighter particles are being transported by airflow (at least in the non-tourist season). Some of the particles trapped in the air filters are undoubtedly derived from the unnatural wall and ceiling deposits in the Snowball Dining Room.

Based upon microscopic observations, it is our opinion that the cohesive black material which coats many of the surfaces in the Snowball Dining Room is largely derived from cooking and heating foods. Our inability to collect these larger particles in air filters operated during the off-season (when no food preparation is done in the Snowball Dining Room) reinforces the idea that the material is associated with food preparation. The sticky material undoubtedly includes food-derived greases. However, based upon the air filter data, food preparation may not be the only important source of the black deposits.

Microscopic observations of some samples from the Snowball Dining Room also disclosed the presence of fungal mycelium. The extent of fungal growth on the gypsum is difficult to quantify; there is no reason to believe that it is only in the form of mycelium. It is worth noting that household plaster and many tile grouts are chemically identical to gypsum. Under moist household conditions (such as around the bathtub) tile grouts often turn black from mold and mildew (which are fungi). The most effective agent for destroying such mold and mildew deposits in the home is bleach (5.25% sodium hypochlorite solution). As we will discuss later in this report, bleach is also the most effective agent for removing the unnatural coatings in the Snowball Dining Room of Mammoth Cave.

During the review of the draft report several comments on the unnatural coatings were received. We emphasize the following. First, that the natural color of the gypsum crust in the vicinity of the Snowball Dining Room is typically near-white, but with a common 10YR hue. Secondly, coloration of the gypsum may be different in other portions of the cave. Thirdly, the black coating on the gypsum in the Snowball Dining Room is not natural. Finally, much (but not all) of the dust which coats gypsum in areas such as the Snowball Dining Room is not natural. Trail construction, cave travel, and altered airflow patterns are involved in the unnatural transport of dust through the cave system.

Microclimate Studies

A characterization of temperature, relative humidity, and airflow patterns in and near the Snowball Dining Room was conducted. Additionally, sampling of airborne particulate matter was conducted for the period of our investigation.

All of the microclimate data were collected by Mr. Bobby Carson of the National Park Service. His high quality work was of great value, and is very much appreciated.

Temperature and Relative Humidity

A recording hygrothermograph was operated in the passage between the Snowball Dining Room and the sewage pumping plant during calendar year 1985. This instrument measured relative humidity and temperature (in degrees F). Mr. Carson provided us with photocopies of all the charts for 1985. We determined the following values from these charts:

1. Maximum, minimum, and mean daily temperatures
2. Maximum, minimum, and mean daily relative humidities

In addition, we calculated mean monthly values for all measured parameters.

Table 1 summarizes monthly temperature and relative humidity values from the Snowball Dining Room area for calendar year 1985. Figure 1 graphically displays these data. Photocopies of the daily values have been sent to Mr. Carson for addition to NPS files.

During the summer (the use season in the Snowball Dining Room) there are routine daily increases in both air temperature and relative humidity in the Snowball Dining Room.

Temperatures in the Snowball Dining Room typically begin to increase at about 10:00 AM, and will increase noticeably until about 12:30 PM. They then increase more slowly until reaching a peak at about 4:00 PM. Temperatures then decrease at a fairly steady rate until about 7:30 PM when they have returned to about the same temperature as existed prior to 10:00 AM. Based upon a sample of 13 days during June, July, and August, 1985, the mean temperature increase associated with the daily cycles is 0.9 degrees F.; daily increases vary from 0.5 to 1.5 degrees F.

Relative humidity values in the Snowball Dining Room also show a daily cycle during summer. Relative humidity begins to increase at about 9:45 AM, and increases within 15 minutes to an hour to a new and fairly constant value. The increased relative humidity persists until about 2:30 PM; it then declines until about 4:00 PM when it has returned to about the same value as existed prior to 9:45 AM. Based upon a sample of 15 days in June, July, August, and September, 1985, the mean increase in relative humidity associated with the daily cycles is 1.5%; increases range from 0.5 to 2.0%.

The almost daily increases in temperature and relative humidity in the Snowball Dining Room reflect use of this chamber. Temperature increases are caused by the

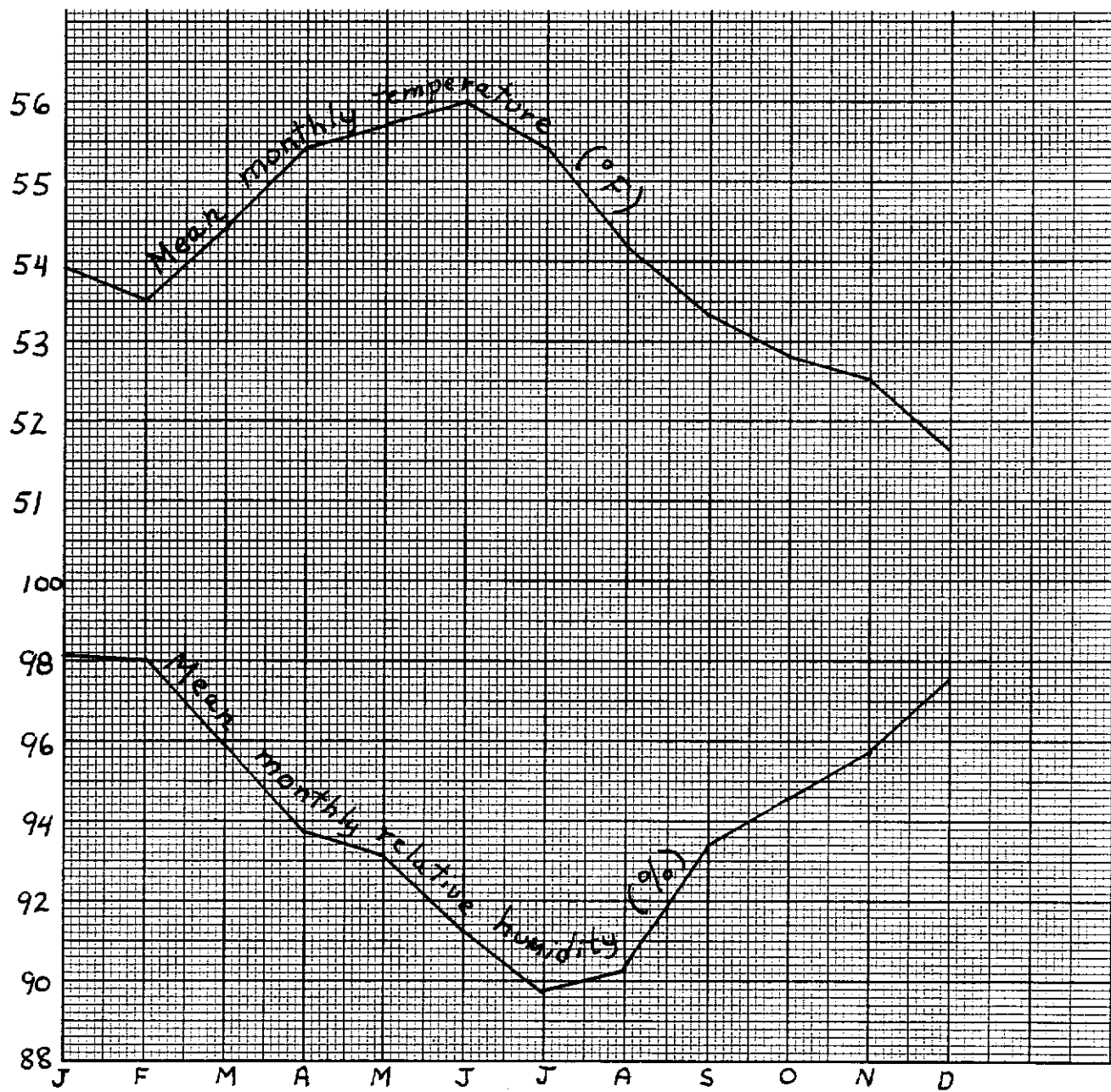
Table 1

Monthly air temperatures and relative humidities in the Snowball Dining Room area for 1985.

	Temperature			Relative humidity		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
January	56.0	52.0	53.9	99.0	95.0	98.1
February	55.2	52.0	53.5	99.0	95.0	98.0
March	56.0	54.0	54.4	98.0	94.0	95.9
April	56.0	54.2	55.4	97.0	91.0	93.7
May	57.0	54.2	55.7	96.0	90.0	93.1
June	57.3	54.5	56.0	93.7	89.3	91.2
July	57.5	54.0	55.4	92.0	88.7	89.7
August	55.3	53.7	54.2	93.3	88.3	90.2
September	55.3	52.0	53.3	96.0	90.0	93.3
October	53.5	52.0	52.8	97.0	92.0	94.5
November	53.3	51.3	52.5	98.0	93.0	95.7
December	52.3	50.8	51.6	98.3	95.8	97.5
Mean annual	55.4	52.9	54.1	96.4	91.8	94.2

Figure 1

Monthly air temperatures and relative humidities in the Snowball Dining Room area for 1985.



electric lights, cooking and heating elements, and by visitors and employees. Some temperature increases may also be associated with the introduction of water into and through the restroom facilities. Relative humidity increases are probably due primarily to steam from hot food; human respiration may also be involved.

There are occasional increases and decreases in relative humidity in the Snowball Dining Room which do not appear to be associated with use of the area. The magnitude and duration of the increases and decreases is more variable than those associated with cave use. Furthermore, such fluctuations occur, on the average, only about once or twice per month.

The routine daily temperature increases are important in transporting grease and other particles upward toward the ceiling of the Snowball Dining Room. At some times increased temperatures and relative humidities in the air of the Snowball Dining Room may be sufficient to cause some condensation on cave surfaces, which in turn might increase the number of particles which become attached to the cave ceiling.

Airflow Directions

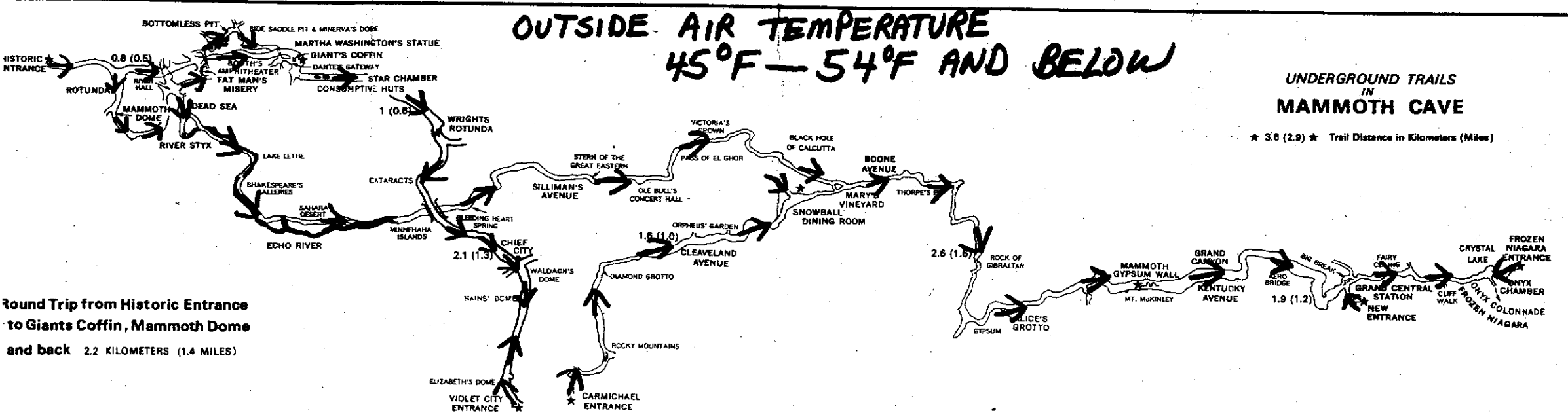
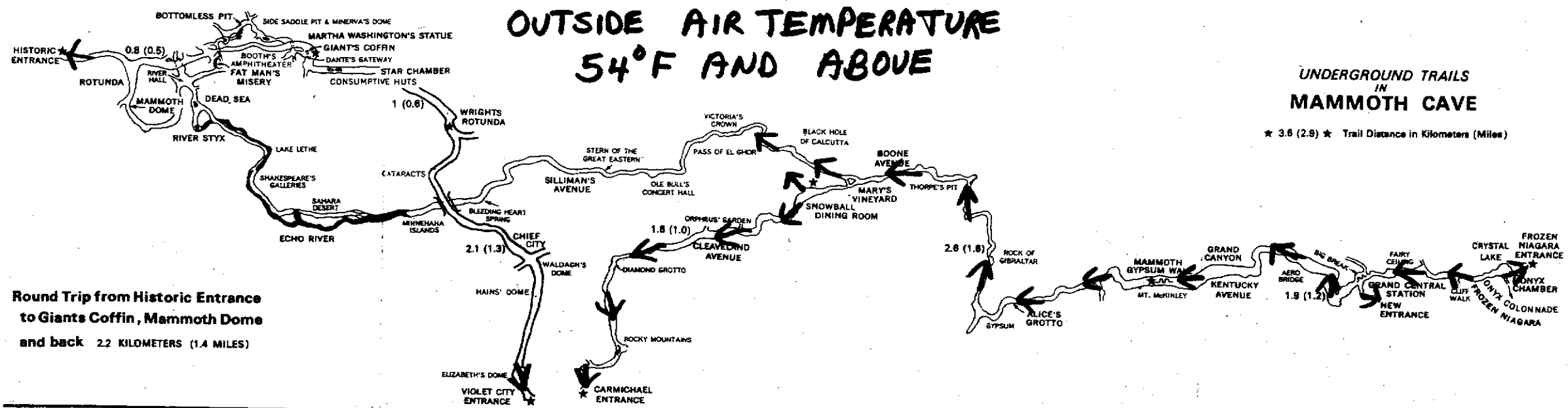
Based upon his experience in Mammoth Cave, Mr. Carson drew maps indicating general air flow directions in the cave. One map depicts conditions when surface air temperatures are greater than about 54 degrees F; the other map depicts conditions when surface air temperatures are less than 54 degrees F. The mean annual temperature of Mammoth Cave is approximately 54 degrees F. Figure 2 is derived from Mr. Carson's maps.

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Mammoth Cave

Figure 2

General airflow directions in Mammoth Cave (data from Bobby Carson, NPS).



Air Quality Monitoring

Mammoth Cave National Park owns equipment for alpha radiation sampling of air within the cave. This equipment consists of a calibrated pump which pulls a known quantity of air through a paper filter. During the course of our study Mr. Carson operated this equipment in the Snowball Dining Room, and periodically sent us the resulting filters.

Almost all of the filters were noticeably grey in color after passing 20,000 to 30,000 liters of cave air. We examined the filters under a microscope, and noted that the discoloration is due primarily to small, flat flecks of black material. This black material apparently consists of carbon compounds. For purposes of comparison we examined a similar filter operated near the TB huts in the cave. It was darker grey than any of the filters from the Snowball Dining Room area. Under microscopic examination, almost all of the discoloration on the filter from the TB huts area was from lint; there were very few of the black flecks which characterized filters from the Snowball Dining Room area. The source of the lint in the filters from the TB huts area is undoubtedly from visitors' clothing.

The black flecks on the air filters operated in the Snowball Dining Room appear to be similar or identical to materials coating gypsum in areas, such as the Upside Down Well, which are somewhat removed from the Snowball Dining Room proper. The black flecks on the filters are small, they do not adhere to each other, and they do not appear to be sticky. The black flecks on the filters seldom if ever have flecks of gypsum dust attached to them. In contrast, the black coatings on surfaces in the Snowball Dining Room appear to adhere to each other and to be sticky. There are numerous dust particles and lint fragments attached to the black coatings in the Snowball Dining Room.

A total of 10 filters from equipment operating in the Snowball Dining Room were examined. Basic data on these filters is shown in Table 2. The filters were numbered to indicate the sampling period, then were arranged in order of decreasing amounts of black material trapped in the filters. The order was as follows:

Filter 6 (2/21 to 3/7/86) contained the greatest amount of trapped material.

Filter 8 (3/27 to 4/15/86)

Filter 4 (1/14 to 1/31/86)

Note: Filters 6, 8, and 4 were very similar to each other.

Filter 3 (12/31/85 to 1/14/86)

Filter 5 (1/31 to 2/21/86)

Filter 10 (5/2 to 5/21/86)

Filter 9 (4/15 to 5/2/86)

Note: Filters 3, 5, 10, and 9 were very similar to each other.

Filter 2 (12/18/85 to 12/31/85)

Filter 7 (3/7 to 3/27/86)

Note: Filters 2 and 7 were very similar to each other and contained noticeably less black material than all above filters.

Filter 1 (12/12 to 12/18/85). Note that this was the shortest sampling period of any of the filters.

Table 2

Data on air filters operated in the Snowball Dining Room during the study.

<u>Filter #</u>	<u>Placed</u>		<u>Recovered</u>		<u>Elapsed Hours</u>	<u>Liters passed</u>	<u>Station</u>
	<u>Date</u>	<u>Time</u>	<u>Date</u>	<u>Time</u>			
1	12/12/85	1320	12/18/85	1220	143	8,580	From elevator area toward Snowball DR
2	12/18/85	1220	12/31/85	1305	312	18,765	same
3	12/31/85	1305	1/14/86	1309	336	20,164	same
4	1/14/86	1309	1/31/86	0920	404	24,250	same
5	1/31/86	0920	2/21/86	1325	493	29,585	same
6	2/21/86	1325	3/7/86	1325	336	20,160	same
7	3/7/86	1325	3/27/86	1350	480	28,825	Flow reversed w/ warmer weather. Now toward elev. area
8	3/27/86	1350	4/15/86	1021	453	27,151	same
9	4/15/86	1021	5/2/86	1332	411	24,660	same
10	5/2/86	1332	5/21/86	1325	456	27,353	same

During most of the period that the filters were in operation there was little or no visitation in the Snowball Dining Room. However, even in the absence of human use in this part of the cave there was a substantial amount of black flecks being transported in airflows which traverse the cave. The amount of airborne transport may increase as cave use increases; we hope to determine this from future filters.

Factors causing difference in the amount of airborne transport of the black flecks of material are unclear in the existing data. Differences in the direction of general airflows in the cave does not appear to account for differences in the amount of material trapped in the air filters.

We have concluded that the black material found in the filters is at least partly derived from the black coatings in the Snowball Dining Room and adjacent areas. We also believe that the black material found in the filters is at least partly derived from other carbon coatings on cave surfaces. Finally, it is possible that some of the black material is derived from "torch throwing" (which uses kerosene-soaked cotton rags); this practice still occurs on the historic tour.

Variations in the amount of black material found in the filters suggests that some non-continuous processes are important in introducing the black material into the air or in keeping it suspended in the air. Air velocities through the cave passages could be a very important factor. Similarly, fluctuations in air temperature and relative humidity could be implicated in the introduction of the black material into the air from cave surfaces.

Our microclimate studies have clearly shown that substantial amounts of black material are currently transported through the air in Mammoth Cave. This material tends to adhere to cave surfaces; it is often found on rough textured gypsum surfaces. The problems with the unnatural black material on cave surfaces in the Snowball Dining Room are three-fold. First, we need to remove these materials. Secondly, we need to minimize or prevent the deposition of similar replacement material. Thirdly, we need to prevent or minimize the addition of any new carbon compounds into Mammoth Cave.

Laboratory Studies of Methods for Removing Unnatural CoatingsSamples

During the period December 11 through 13, 1985 we visited the Snowball Dining Room with Mr. Jim Wiggins and Mr. Bobby Carson of the National Park Service. A primary purpose of this visit was to collect samples of gypsum which had unnatural coatings.

To the extent possible all samples collected were already broken. Most of the samples were small. We attempted to collect samples which displayed a wide range of texture conditions and a wide range of thicknesses of unnatural coatings.

All sample collection sites were numbered and described in field notes. All samples were wrapped in tissue and then placed in sealed plastic bags, which were in turn packed in a cardboard box. The packing was done in the Snowball Dining Room. The samples were then transported to the Ozark Underground Laboratory for laboratory studies.

Test Products

Based largely upon discussions of various compounds in DiStasio (1981) we selected 44 potential cleansing agents for study. These agents included acids, bases, solvents, reducing agents, oxidizing agents, detergents, sequesterants, surfactants, degreasers, and biocides.

DiStasio (1981) provides a good explanation of surfactants and sequesterants. He states: "Surfactants (surface active agents) are organaic chemical wetting, cleaning and disinfecting agents. They find wide utility in such diverse products as detergent and washing compounds, water softeners, textile softeners, antistatic agents, lubricants, in oil well operations, in plastics manufacture, in shampoos, cosmetics, and medicinal agents. Detergent builders and sequesterants (which we have considered together in our Mammoth Cave studies) are often used in conjunction with surfactants. One outstanding property of sequesterants is the formation of stable, soluble complex ions with metals. The sequesterants, or chelating agents, can improve the washing power of surfactant mixtures, stabilize emulsion systems, and can also be used alone in certain specialized cleaning products such as for the removal of scale and sludge from metal surfaces."

Our selection of test products incorporated an extremely wide range of potential cleansing agents. The basic purpose of our selection of study agents was to develop a good understanding of how various types of agents would affect the unnatural gypsum coatings and the gypsum itself. In our selection of the 44 agents we did not exclude compounds which had properties that might limit or prevent their use in Mammoth Cave. Instead, our plan was to learn which types of agents produced apparently beneficial results. Our rationale was that once we learned the types of agents which would and would not work, we could then search for specific compounds (or groups of compounds) which might potentially be useful in Mammoth Cave.

Table 3 identifies the 44 cleansing compounds tested on unnatural gypsum coatings collected from the Snowball Dining Room. Each agent was assigned a number which is indicated in the table. To the extent possible Table 3 identifies the nature of the cleansing agent. This identification is sometimes difficult because compound contents are often incompletely listed and are seldom quantified.

Table 3

Cleansing compounds tested on unnatural coatings on gypsum from the Snowball Dining Room. To the extent possible the nature of the active cleansing agents in the tested compound is identified.

1. ACS Anti-Crea-Soot. Surfactant. May also include reducing agents, degreasers, or detergents.
2. Chimney Sweep. Surfactant.
3. Gillespie Furniture Cleaner. Solvent.
4. Clear Ammonia. Reducing agent.
5. Lime-a-Way. Acid.
6. Grease Relief. Surfactant, acid, and degreaser.
7. Formula 409. Acid, sequesterant, degreaser, detergent.
8. Advanced Formula Spray n Wash. Surfactant, sequesterant, detergent.
9. Thicker Formula Shout. Surfactant, sequesterant, detergent.
10. Clorox Prewash. Surfactant, sequesterant, detergent.
11. Easy Wash. Surfactant, sequesterant, detergent.
12. Miracle White. Surfactant and sequesterant.
13. Kitchen Magic. Solvent.
14. Tile n' Grout Magic. Sequesterant, oxidizing agent, and possibly an acid.
15. K2r. Solvent.
16. Ronsonol Lighter Fluid. Solvent.
17. Mr. Muscle. Reducing agent, strong base.
18. Liquid Plumr. Reducing agent, oxidizing agent, strong base.
19. CO Contact Cleaner. Solvent and degreaser.
20. Hydrogen Peroxide. Oxidizing agent.
21. Trisodium Phosphate. Detergent and sequesterant.
22. Gunk Tar and Bug Remover. Solvent.
23. Gunk Engine Brite. Solvent.
24. Du Pont Formula 7 Car Wash. Surfactant and detergent.
25. Driveway Cleaner. Sequesterant and solvent.
26. B-12 Chem Tool. Solvent.
27. Lacquer Thinner. Solvent.
28. Turpex. Solvent.
29. Strypeeze. Solvent and strong base.
30. Turpentine. Solvent.
31. Window Clean. Solvent.
32. Sani-Flush. Surfactant and acid.
33. Brasso. Reducing agent and solvent.
34. Crystal Drano. Reducing agent and strong base.
35. Clorox. Oxidizing agent.
36. Washing Soda. Surfactant, reducing agent, detergent, and sequesterant.
37. Wisk. Surfactant and detergent.
38. Vinegar. Acid.
39. Water.
40. Simple Green. Surfactant, detergent and oxidizing agent.
41. Potassium Hydroxide in 70% isopropyl alcohol. Strong base and solvent.

- 42. 37% Formaldehyde. Biocide.
- 43. Tinactin. Biocide (fungicide).
- 44. Quinsana. Biocide (fungicide).

Standard Test A

We used a standard treatment approach for evaluating all 44 selected cleansing compounds. The nature of some of the compounds made it impossible for all treatments to be identical.

The standard treatment (which we have called Test A) consisted of placing a small piece of gypsum with the unnatural black coating in a screw cap bottle. The sample was then immersed in the cleansing agent being tested; the time of this treatment was recorded. After a period of at least 15 minutes the test cleansing agent remaining in the sample bottle was poured through a piece of filter paper; the time was again recorded. If product instructions recommended a contact duration time, this recommendation was followed in lieu of the minimum 15 minute test.

After the test product was poured from the sample, the sample was rinsed with unchlorinated water from a hand spray bottle (such as those commonly used in the house). The rinse water was then poured through the filter paper. Observations were made in laboratory notes, and the filter paper was dried for any future investigation which might be warranted.

The performance of each cleansing test was qualitatively ranked into six classes:

1. Ineffective performance. Little or none of the unnatural black coating was removed by the cleansing agent and/or the rinse water.
2. Fair performance. Some (but less than 20%) of the unnatural black coating was removed by the cleansing agent and/or the rinse water.
3. Fair to good performance. About 20 to 30% of the unnatural black coating was removed by the cleansing agent and/or the rinse water.
4. Good performance. About 30 to 40% of the unnatural black coating was removed by the cleansing agent and/or the rinse water.
5. Good to very good performance. About 40 to 50% of the unnatural black coating was removed by the cleansing agent and/or the rinse water.
6. Very good performance. More than 50% of the unnatural black coating was removed by the cleansing agent and/or the rinse water.

Table 4 summarizes the observed cleansing performance from Test A of the 44 tested products. This is solely a ranking on cleansing performance and not of any other factors.

Table 4

Performance of cleansing agents tested on unnatural coatings on gypsum from the Snowball Dining Room. See text for description of cleansing performance classes.

1. ACS Anti-Crea-Soot. Fair
2. Chimney Sweep. Ineffective
3. Gillespie Furniture Cleaner. Fair.
4. Clear Ammonia. Ineffective.
5. Lime-a-Way. Very Good.
6. Grease Relief. Good.
7. Formula 409. Fair.
8. Advanced Formula Spray n Wash. Fair to Good.
9. Thicker Formula Shout. Fair.
10. Clorox Prewash. Good.
11. Easy Wash. Good.
12. Miracle White. Good.
13. Kitchen Magic. Fair.
14. Tile n' Grout Magic. Good.
15. K2r. Very Good.
16. Ronsonol Lighter Fluid. Fair.
17. Mr. Muscle. Ineffective.
18. Liquid Plumr. Very Good.
19. CO Contact Cleaner. Good.
20. Hydrogen Peroxide. Fair to Good.
21. Trisodium Phosphate. Good.
22. Gunk Tar and Bug Remover. Good.
23. Gunk Engine Brite. Good.
24. Du Pont Formula 7 Car Wash. Very Good.
25. Driveway Cleaner. Fair.
26. B-12 Chem Tool. Fair to Good.
27. Lacquer Thinner. Good.
28. Turpex. Good.
29. Strypeeze. Good to Very Good.
30. Turpentine. Good.
31. Window Clean. Good.
32. Sani-Flush. Fair to Good.
33. Brasso. Fair.
34. Crystal Drano. Good.
35. Clorox. Very Good.
36. Washing Soda. Ineffective.
37. Wisk. Fair.
38. Vinegar. Fair to Good.
39. Water. Fair.
40. Simple Green. Fair to Good.
41. Potassium Hydroxide in 70% isopropyl alcohol. Good.
42. 37% Formaldehyde. Fair.
43. Tinactin. Fair.

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44. Quinsana. Fair.

Summary

5 products rated Very Good
1 product rated Good to Very Good
15 products rated Good
6 products rated Fair to Good.
11 products rated Fair
6 products rated Ineffective.

Based upon data in Table 3 and Table 4 we conducted a ranking analysis to help evaluate the cleansing performance of various classes of agents. The ranking analysis is shown in Table 5, and was conducted as follows. First, 10 different classes of agents were identified from the data in Table 3. These were surfactants, acids, reducing agents, detergents, sequesterants, solvents, oxidizing agents, degreasers, strong bases, and biocides. The number of products containing each of these identified classes of agents was recorded, and the number in each cleansing performance category was shown (see Table 5). Arbitrary values were assigned to each of these classes; the values were as follows:

Ineffective cleansing performance: 0
Fair cleansing performance: 1
Fair to good cleansing performance: 2
Good cleansing performance: 3
Good to very good cleansing performance: 4
Very good cleansing performance: 5

The above arbitrary values were multiplied by the number of products in each performance class; this permitted the calculation of a mean cleansing performance value. These values are shown in the far right hand column in Table 5; the mean values range from 1.5 to 3.4. Based upon this analysis, the general performance of various types of cleansing agents appears to be as follows:

Oxidizing agents are best; they are better than strong bases, which in turn appear to be substantially better than any other types of agents. Strong bases are better than acids; acids are similar in performance to degreasers and solvents, which in turn are better than surfactants, sequesterants, and detergents. Biocides and reducing agents are the least effective in removing the unnatural black coatings from the gypsum.

Table 5

Ranking analysis of various classes of cleansing agents. Results from Test A.

<u>Type of Agent</u>	<u>Number</u>	<u>Number of Products</u>						<u>Mean Cleansing Performance Value*</u>
		<u>Ineffec- tive</u>	<u>Fair</u>	<u>Fair- Good</u>	<u>Good</u>	<u>Good- Very Good</u>	<u>Very Good</u>	
Surfactants	13	2	3	3	4	0	1	2.0
Acids	5	0	1	2	1	0	1	2.4
Reducing Agents	6	3	1	0	1	0	1	1.5
Detergents	10	3	1	2	3	0	1	1.9
Sequesterants	10	1	3	1	5	0	0	2.0
Solvents	15	0	5	1	8	1	0	2.3
Oxidizing Agents	5	0	0	2	1	0	2	3.4
Degreasers	3	0	1	0	2	0	0	2.3
Strong Base	5	1	0	0	2	1	1	3.0
Biocide	4	2	1	0	0	0	1	1.5

*Calculation explained in text.

Arbitrary assigned point values were as follows:

Ineffective	0
Fair	1
Fair to Good	2
Good	3
Good to Very Good	4
Very Good	5

Observations were made during Test A of apparent problems associated with various compounds. There were four identified problems:

1. Difficulty in removing the product from the gypsum.
2. Visible damage to gypsum (such as by solution).
3. Fumes or odors.
4. General toxicity of the compound.

The apparent extent of each of the above four problems was assessed for each tested compound. Four categories were used in this assessment:

A) No detectable problem.

B) Little problem. The problem seemed to be minor, and would probably not significantly interfere with the potential use of the product in the cave.

C) Moderate problem. The problem seemed to be of sufficient extent to possibly limit the potential use of the product in the cave. Reasonable methods of minimizing the problem might exist.

D) Severe problem. The problem seemed to be of sufficient extent to significantly limit (and potentially prohibit) the use of the product in the cave. Reasonable methods of minimizing the problem might exist in the case of products which were difficult to remove from the treated gypsum.

Table 6 summarizes the identified problems and their respective severities for 27 products with cleansing performance ranked "Fair to Good" or better. Products with cleansing performance ranked Ineffective or Fair (see Table 4) are omitted.

Based upon the identified problems and their apparent severity we then made a preliminary assessment of the likely limitations on cave use of each of the products. This determination is shown in Table 6 under the heading "Problems if used in cave".

Table 6

Preliminary assessment of potential problems associated with various cleansing products tested.

<u>Product number and name</u>	<u>Test A Cleansing perform</u>	<u>Problems if used in cave</u>	<u>Hard to remove product</u>	<u>Damage to gypsum</u>	<u>Fumes</u>	<u>General toxicity</u>
5. Lime-a-way	VG	L	—	L	—	—
6. Grease Relief	G	M	S	—	—	—
8. Spray n'Wash	F-G	M	S	—	—	—
10. Clorox Prewash	G	M	S	—	—	—
11. Easy Wash	G	M	S	—	—	—
12. Miracle White	G	M	S	—	—	—
14. Tile 'n Grout Magic	G	M	S	—	—	—
15. K2r	VG	S	—	S	S	S
18. Liquid Plumr	VG	L	—	L	—	—
19. CO contact cleaner	G	M	—	—	—	M
20. Hydrogen Peroxide	F-G	L	—	—	—	—
21. Trisodium Phosphate	G	L	—	—	—	—
22. Gunk Tar & Bug Remover	G	S	M	S	S	S
23. Gunk Engine Brite	G	S	S	S	S	S
24. DuPont Form 7	VG	L	—	L?	—	—
26. B-12 Chemtool	F-G	S	M	S	S	S
27. Lacquer Thinner	G	S	M	M	S	S
28. Turpex	G	S	M	—	S	S
29. Strypeeze	G-VG	S	M	—	S	S
30. Turpentine	G	L	M	—	—	—
31. Window Clean	G	S	S	—	S	S
32. Sani-Flush	F-G	M	—	M	—	—
34. Crystal Drano	G	M	—	M	—	—
35. Clorox	VG	L	—	—	L	—
38. Vinegar	F-G	L	—	L	—	—
40. Simple Green	F-G	L	S	—	—	—
41. KOH in 70% isopropyl	G	L	—	—	—	—

Note: L = Little, M = Moderate, S = Severe, F-G = Fair-Good, G = Good, G-VG = Good-Very Good, and VG = Very Good.

Standard Test B

All ten cleansing agents classed as presenting little potential cave problems in Table 6 were selected for Test B. In addition, two of these products (Product 21, Trisodium phosphate and Product 35, Clorox) were combined and tested as Product 45. Label instructions on Product 21 suggested this combined use.

Test B used gypsum samples from the Snowball Dining Room which were coated with the unnatural black material. A large piece of sample material from Station 28, which was over the comfort station sign, was broken into 12 pieces. One piece was used as a control; the other pieces were treated with various products.

In Test B the samples were placed flat and the test solution was poured or sprayed on the sample and then left for 30 minutes. Unlike Test A, the samples were not in bottles and the samples were not immersed in the test solution. After 30 minutes of exposure to the test solution the samples were rinsed with unchlorinated water from a spray bottle.

The samples were then allowed to dry. Observations were made as to the relative effectiveness of the applied treatment, and the samples were arranged from best apparent treatment to worst apparent treatment. The relative rankings were recorded as results from Test B-1.

Next, the samples were again treated with the same product. One hour after treatment the samples were again rinsed with unchlorinated water from a spray bottle. They were then allowed to dry, and again arranged from best apparent treatment to worst apparent treatment. These ranking were recorded as results from Test B-2. Differences in results between Tests B-1 and B-2 were generally small. Test B-2 is believed to provide a better assessment than Test B-1.

Table 7 summarizes the cleansing performance of the 11 tested compounds used in Test B. For convenience, this table shows performance in Tests A, B-1, and B-2.

In the B series of tests Product 35 (Clorox) was by far the most effective cleansing agent. In Test B-2, products 5, 18, 45, and 38 produced very similar results. Products 30, 21, 40, and 20 also produced similar results.

Table 7

Cleansing performance of 11 cleansing agents.

<u>Product</u>	Cleansing Performance*		
	<u>Test A</u>	<u>Test B-1</u>	<u>Test B-2</u>
5. Lime-a-way	VG	4	2
18. Liquid Plumr	VG	3	3
20. Hydrogen peroxide	F to G	9	11
21. Trisodium Phosphate	G	7	9
24. Du Pont Formula 7 Car Wash	VG	6	6
30. Turpentine	G	9	8
35. Clorox	VG	1	1
38. Vinegar	F to G	2	5
40. Simple Green	F to G	9	10
41. Potassium Hydroxide in 70% isopropyl alcohol	G	11	7
45. Trisodium Phosphate + Clorox	not rated	5	4

* F to G = Fair to Good, G = Good, VG = Very Good. Tests B-1 and B-2 were ordered from best performance (1) to poorest performance (11).

Test Results for the 45 Products Tested

The following pages present test results and associated data on the 45 cleansing products which were used in laboratory testing. The data sheets present the following information about each of the products:

1. Product number and name.
2. The typical function of the product.
3. Label directions for use of the product.
4. Cautionary information (largely from label directions).
5. Name and address of manufacturer.
6. Size of container and price (some prices are missing).
7. Test results including a ranking of performance and general observations on performance and problems (if any).

Product 1. ACS Anti-creo-soot

Function: A "liquid catalyst" for wood stoves and fireplaces. Controls dangerous creosote and soot that cause chimney fires. Non-combustible; no corrosive chemicals. Active from 300 degrees F , changes composition of creosote in the chimney and firebox for easy removal.

Directions: Spray ACS liberally into fire box and onto wood under low fire conditions. Then build up a good fire. For best results, use on a regular basis.

Caution: Irritant. Harmless when used as directed. Avoid eyes, mucous membranes, or prolonged skin contact. In case of emergency, flush with cold water. Keep out of reach of children. If spilled on textiles, dilute with water.

Product of: Rolfite Products, Inc. Stamford, Conn. 06901

Price: 1 fluid quart, \$13.95

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 18 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. The test product appears to break some of the bonding between the black materials and the gypsum. Cleansing performance rated FAIR.

Product 2. Chimney Sweep Stove and Fireplace Glass Door Cleaner.

Function: Removes film from smoke, soot, and creosote which adheres to glass doors.

Directions: Spray on glass and wipe clean with cloth or paper towels. For baked on deposits, spray again, allow a few minutes to penetrate and wipe clean with rough towel.

Caution: Avoid contact with eyes. If contact occurs flush with water. If taken internally, induce vomiting and drink citrus juices. Call physician. Keep out of reach of children.

Contents: Harmless to normal skin. Will not harm metal or painted surfaces. Contains no acids.

Product of: Coughlan Products, Inc., Clifton, N.J. 07013

Price: 15 fl. oz., \$2.60

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 26 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were some black flecks of materials which had been attached to the gypsum present on the filter. It was difficult to rinse the "soapy" material from the sample. Most of the material which was removed came off during the rinse period. Cleansing performance rated INEFFECTIVE.

Product 3. Gillespie Furniture Cleaner

Function: Removes old wax, polish, oils, and dirt from furniture. It also brightens and revitalizes the furniture finish.

Directions: Dampen a clean soft cloth with Gillespie furniture cleaner and rub the entire surface of the furniture briskly to remove and dissolve the old polish and oil. Then dampen another clean cloth with Gillespie furniture cleaner and wipe the entire surface to remove any residue left from the first application. Your furniture is now ready to polish.

Caution: Harmful or fatal if swallowed. Combustible. Do not use near a fire or flame. Use in well ventilated area. First aid: if swallowed, do not induce vomiting. Call a physician or poison control center immediately. If splashed to the eyes, immediately flush with water for at least 15 minutes. Keep out of reach of children.

Contents: Contains petroleum distillates.

Product of: Klean-Strip, Div. of W.M. Barr Co., Inc. Memphis, TN 38101.

Price: 8 fl. oz., \$1.79

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 31 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product has a strong petroleum odor. What appears to be the petroleum distillate floats on top of the water which has passed through the filter; the petroleum layer is black with dissolved materials. Additionally, a few black flecks of materials which had been attached to the gypsum were present on the filter. The test product appears to dissolve some of the black material. Cleansing performance rated FAIR.

Product 4. Topco Clear Ammonia

Function: For all household cleaning

Directions: Laundry: one cup/load. General cleaning: 1/2 cup to 1 gallon of water.

Caution: Avoid contact with skin and eyes. Do not take internally. Do not mix with chlorine type bleaches or other household chemicals. Keep out of reach of children. If swallowed give large amount of milk or water. Call a physician. External--flood with water. Eyes--flush thoroughly with warm water. Call a physician.

Contents: There is no contents label on the bottle, just the name of the product "clear ammonia".

Product of: Topco Assoc., Inc., Skokie, IL 60077

Price: 32 fl. oz. (1 qt.), \$.43

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 19 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product did not remove appreciable amounts of the materials on the gypsum. The odor of ammonia was very strong. Cleansing performance rated **INEFFECTIVE**

Product 5. Lime-a-way

Function: A non-abrasive liquid that cleans hard water stains including lime, scale, rust and other hard-water deposits. It leaves tiles, tubs, sinks, and fixtures shiny clean without scrubbing or scratching.

Directions: Wearing household gloves, apply with damp sponge or cloth. Use full strength for heavy mineral deposits and stains or mix with equal parts of water. Rinse cleaned surface promptly after use.

Caution: Harmful if swallowed. Avoid contact with eyes and prolonged contact with skin. Use in well ventilated area. Do not mix or use with any other product, especially bleach or mildew stain removers, as toxic fumes may result. If swallowed, do not induce vomiting. Immediately rinse mouth, then drink 1 or 2 large glasses of water or milk. Do not give carbonates or bicarbonates. For skin contact, flush thoroughly with cool running water. In case of contact with eyes, immediately flush with cool running water. Remove any contact lenses. Continue flushing for at least 15 minutes. If fumes result, immediately move to fresh air. Get medical attention immediately.

Lime-a-way may etch some ceramic tiles, tubs and sinks. If in doubt, test small surface area first. Avoid contact on wood or clothing. Do not use on marble, polished aluminum, metallic glazed surfaces, terrazzo, or colored grout.

Contents: Contains phosphoric and hydroxyacetic acid.

Product of: Economics Laboratory, Inc. St. Paul, MN 55102 For emergency medical information call toll free 1-800-328-0026.

Price: 16 fl. oz., \$1.60.

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 13 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

Prior to rinsing there was not much of the black deposits from the gypsum present in the solution. However, when the sample was rinsed the spray water almost totally knocked off the black coating. The test product appears to break (or dissolve) the bonding between the black materials and the gypsum. Cleansing performance rated VERY GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

Ozark Underground Laboratory

Mammoth Cave

This product was the 4th most effective product tested in Test B-1, and the 2nd most effective product tested in Test B-2. The product produced substantial green discoloration of the gypsum sample.

Product 6. Grease Relief

Function: All purpose degreaser and cleaner for kitchen, laundry, and the whole house.

Directions: For large areas use 1/4 to 1/2 cup per gallon water. Use full strength for tough jobs and on laundry.

Caution: Avoid contact with eyes. In case of contact rinse immediately with water. Keep out of reach of children.

Contents: Contains no phosphorus. Does contain surfactants.

Product of: Textize, Division of the Dow Chemical Company, Greenville, S.C. 29602.

Price: 22 fluid oz., \$1.49.

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 31 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. The test product appears to break some of the bonding between the black materials and the gypsum. It was difficult to rinse the "soapy" product off the gypsum; it kept making more foam. Cleansing performance rated GOOD.

Product 7. Formula 409

Function: All purpose cleaner

Directions: Spray onto soiled area. Wipe dry. No rinsing. On washable fabrics, saturate soiled area, rub gently, launder as usual.

Caution: 409 is safe on most washable surfaces. However, on painted surfaces test a small area. Not recommended for use on soft vinyl, varnishes or aluminum. If sprayed on those surfaces, rinse and wipe dry immediately.

Contents: Water, detergents, detergent builder, grease cutter, color. Contains no phosphorus.

Product of: The Clorox Company, Oakland, CA 94612

Price: 22 fluid oz., \$1.76.

Test Results:

Test A. A chip of gypsum from the ceiling directly opposite the serving area in the Snowball Dining Room was used; this was sampling station 2. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 26 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were some black flecks of materials which had been attached to the gypsum present on the filter. The test product appears to break some of the bonding between the black materials and the gypsum. Cleansing performance rated FAIR.

Product 8. Advanced Formula Spray 'n Wash

Function: Laundry soil and stain remover with brighteners.

Directions: Saturate soiled area thoroughly. Wash with regular detergent within 2 minutes of pre-treating.

Caution: Will not remove rust, dried paint, permanent ink, dye or bleach stains. Avoid contact with eyes. In case of eye contact, flush with water for 15 minutes. If irritation persists, seek medical attention. Keep away from children.

Contents: Does not contain phosphorus. Does contain surfactants.

Product of: Textize, a division of The Dow Chemical Co., Greenville, SC, 29602.

Price: 22 fluid ounces \$2.05.

Test Results:

Test A. A sample of gypsum from Station 30 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 13 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. It was very difficult to rinse the "soapy" product off the gypsum. Cleaning performance rated FAIR to GOOD.

Product 9. Thicker Formula Shout

Function: Laundry stain remover

Directions: Saturate the stain, wait one minute, launder with regular detergent in the hottest water the fabric will accept. Do not allow Shout to dry before laundering.

Caution: Rust, bleach damage, dried paint or permanent ink or dyes may be impossible to remove. Keep out of reach of children. If product gets in eyes, rinse thoroughly with water. If irritation continues, contact a physician. Do not treat garment while wearing.

Contents: None listed

Product of: S.C. Johnson and Son, Inc. Racine, WI 53403 Questions?? Call 800-558-5252 Weekdays 9-5 Eastern Time or write Carol Hansen.

Price: 22 fluid ounces \$1.89.

Test Results:

Test A. A sample of gypsum from Station 30 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 20 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were a few small black flecks of the materials which had been attached to the gypsum present on the filter; there were no large pieces. The test product appears to break some of the bonding between the black materials and the gypsum. Cleansing performance rated FAIR.

Product 10. Clorox Prewash

Function: Laundry soil and stain remover. Works on food, grease, dirt, and soil. Safe for all washable colors and fabrics.

Directions: Saturate soiled area, rub, wait 3-5 minutes, wash with detergent.

Caution: Eye irritant. In case of eye contact, flush thoroughly with water. Call a physician. Keep out of reach of children.

Contents: Contains ethoxylated alcohols. Does not contain phosphates, enzymes, or bleach.

Product of: The Clorox Co., Oakland, CA 94612

Price: 16 fluid ounces \$1.77.

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 19 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

A substantial amount of the black materials which had been attached to the gypsum were removed. Some of the removed materials were particles on the filter, the balance passed through the filter and discolored the filtrate. It was very difficult to rinse the "soapy" material from the sample. Cleansing performance rated GOOD.

Product 11. Easy Wash

Function: Laundry soil and stain remover. Safe for all washable fabrics.

Directions: Saturate soiled area, wait one to three minutes, wash with detergent.

Caution: In case of eye contact, flush well with water.

Contents: Contains no harsh bleach, caustics or enzymes.

Product of: Van Wyck Products Co., Inc. Pasadena, CA 91101

Price: 12 fl. oz., \$2.39

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 24 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There was a substantial amount of removal of the black material which had been coating the gypsum. Much of the removal of this material occurred during the rinse phase. Much of the black material passed through the filter and could be seen in the filtrate. The product is extremely "soapy", and it was very difficult to rinse it from the gypsum sample. Cleansing performance rated GOOD.

Product 12. Miracle White

Function: Detergent booster. Lifts greasy stains, whitens whites, brightens colors without bleach. Safe on all washables. Effective on oil, collar/cuff grime, grass, ground in dirt, chocolate, and many other stains.

Directions: Add 1/2 cup to washer with detergent.

Caution: Eye irritant. In case of eye contact, flush with water for 15 minutes. If irritation persists, call a physician. Keep out of reach of children.

Contents: Contains nonionic surfactant. Does not contain bleach.

Product of: KIWI Brands Inc., Douglassville, Pa 19518

Price: 32 fluid ounces, \$2.00.

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 26 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

This product did remove some of the black material attached to the gypsum. There were many black particles on the filter. It was hard to rinse the "soapy" material from the gypsum. Cleansing performance rated GOOD

Product 13, Kitchen Magic

Function: Gives a tough silicone shield to all kitchen surfaces without streaking. Resists staining or discoloration. Restores beauty and brightness to all kitchen surfaces. Removes food stains and deposits, cooking grease, finger marks, dulling film (great for bathroom fixtures).

Directions: (Aerosol). Shake well. Spray small area and wipe over surface with soft clean cloth until dirt and stains are gone. While surface is still moist, wipe to a gleaming finish with a dry soft cloth.

Caution: Keep out of reach of children. Harmful or fatal if swallowed. If swallowed do not induce vomiting. Call physician immediately. Spray in well ventilated area. Avoid prolonged breathing of vapors. In case of eye contact, flush with water.

Contents: Contains petroleum distillates. Environmentally safe propellant.

Product of: Magic American Chemical Corp., Cleveland, Ohio 44122

Price: 13 oz., \$2.79

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 1 minute, then sprayed again. After the second spraying, the product was allowed to stand on the sample for 17 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There was an apprecable amount of removed materials present on the filter. However, there was still a substantial amount of material remaining on the sample. The product has an extremely strong odor, almost like insecticide. Additionally, the cleanup with water was extremely difficult; the cleansing agent clings to the sample and produces a compound rather like a liquid cottage cheese. The cleansing performance was rated FAIR

Product 14. Tile'n Grout Magic

Function: Removes surface grime, hard water stains, and soap film. Cleans and brightens. Safe on ceramic, plastic, metal and mosaic tile and porcelain. Removes mold and mildew stains and odors and helps control their growth. Polishes, disinfects, kills odor causing germs.

Directions: A spray foam. Shake well. Spray surface. Rinse only when polishing chrome or if surface may come in contact with food. For deep cleaning, leave the foam on the surface for 10 minutes before wiping, then reapply and wipe with a damp cloth (do not dry).

Caution: Hazardous to humans and domestic animals. Causes eye and skin irritation. Do not get in eyes. Avoid skin contact. In case of contact, flush with water. If irritation persists, get medical attention. Avoid contact with food.

Contents: Does not contain harsh abrasives or caustic acids to scratch, mar or dull fixtures. Active ingredients: n-Alkyl (60% C14, 30% C16, 5% C12, 5% C18) dimethyl benzyl ammonium chlorides 0.1%, n-Alkyl (68% C12, 32% C14) dimethyl ethylbenzyl ammonium chlorides 0.1% Inert ingredients: 99.8%

"Note: It is a violation of federal law to use this product in a manner inconsistent with its labeling."

Product of: Magic American Chemical Corp. Cleveland, Ohio 44122

Price: 13 ounces \$2.95

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 20 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The washing phase removed much of the black material which had been attached to the gypsum; this material was deposited in small pieces on the filter. The test product appears to break some of the bonding between the black materials and the gypsum. It is somewhat difficult to remove the cleansing agent with only water. Performance rated GOOD.

Product 15. K2r

Function: Spot-lifter for carpets, clothing, upholstery, wallpaper (dry-cleanable fabrics, polyester, acrylic, nylon, wool blends--regular and knits) Do not use on rubber, suede, plastic, latex, acetate, velvet, varnished surfaces. Removes spots of alcoholic beverages, catsup, mustard, mayonnaise, eggs, grease and oil, black coffee, soft drinks, milk and cream without sugar, fruit juices, hair tonic, lipstick, perfume, and many others. Used more than once it will remove ball-point ink, crayon, grass, soot, tar, typewriter ribbon. First use water and then K2r on cake and candy, flour-based gravy, honey, ice cream, jams and jellies, puddings, salad dressings, soy sauce, etc.

Directions: Aerosol. Shake can well. Spray to cover spot, do not saturate. Let K2r dry completely. Brush away powder.

Caution: Do not spray in eyes or on skin. If contact occurs, flush thoroughly with water. Avoid prolonged breathing of vapor. Keep away from children.

Contents: Contains perchloroethylene and trichloroethane

Product of: Textize, a division of Morton Thiokol, Inc., Greenville, S.C. 29602

Price: 6 oz. \$2.59

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 21 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product is very destructive to gypsum; it seems to destroy it even more than acid does. The filtrate from the sample, when shaken, is translucent with suspended and dissolved gypsum.

There was abundant "greasy" material left on the filter paper. The cleansing performance was VERY GOOD; this may be because gypsum beneath the attached material is destroyed. The sample appears to have a different texture after treatment; the surfaces appear to be smoother.

Product 16. Ronsonol Lighter Fluid.

Function: Lighter fluid. Commonly used as a spot remover.

Directions: Saturate spot. Rub. Launder.

Caution: If the skin becomes irritated, flush with plenty of water. If swallowed do not induce vomiting. Call physician immediately. Flammable.

Contents: Naphtha

Product of: Ronson Corporation, Woodbridge, N.J. 07095

Price: 7 fl. oz. \$.59

Test Results:

Test A. A sample of gypsum from Station 31 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 26 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. Essentially all removal of materials occurs during the washing phase. There was no visible change in the appearance of the lighter fluid. Performance rated FAIR.

Product 17. Mr. Muscle

Function: Oven cleaner. Lifts off baked-on grease.

Directions: Aerosol. Shake can well. Spray on oven walls. Let set 30 minutes. Wipe off.

Caution: Product is caustic and causes burns to skin and eyes. Wear rubber gloves and protect arms when spraying and wiping oven. Wash after use. Harmful if swallowed. Avoid breathing spray mist. If contacts eyes, rinse eyes immediately for 15 minutes. If swallowed, rapidly rinse mouth, then immediately drink a glassful of milk or water. Do not induce vomiting. If it contacts skin, remove affected clothing. Flush with water for 15 minutes to remove all traces of product. Call physician, poison center or emergency room.

Do not use on continuous or self-cleaning ovens. Do not spray on or let foam contact pilot lights, electrical connections, switches, light bulbs, heating elements, receptacles, and thermostats. Spray may cause an electrical short. Do not let product contact floor coverings, linoleum, exterior oven surfaces, aluminum, copper, chrome, painted surfaces, or plastics.

Contents: Caustic. Contains about 4% sodium hydroxide (lye).

Product of: The Drackett Products Co., Cin., OH 45232

Price: 8 oz., \$1.49

Test Results:

Test A. A sample of gypsum from Station 29 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then sprayed with the test product. The product was left on the test material for 38 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The solution which was washed from the sample looked dirty, but the sample was still very black with attached material. The washing does not remove much of the black material. It is difficult to wash the product off the sample. Additionally, the rinsed material does not go through the filter paper. Performance rated INEFFECTIVE

Product 18. Liquid-Plumr

Function: Drain opener.

Directions: Pour slowly over drain opening, allow to work for 30 minutes, flush with hot tap water.

Cautions: Keep out of reach of children. Harmful if swallowed. Injures eyes and mucous membranes on contact. Do not use Liquid-plumr with ammonia, toilet bowl cleaners or other drain openers; splashing or the release of hazardous gases may occur. Clean up any spillage immediately. Eyes--flush immediately with water. External--wash immediately with water. Internal--drink large quantities of water. Do not induce vomiting. Call physician. Do not use plunger with Liquid-plumr. Will not harm pipes or disposers.

Contents: Water, sodium hypochlorite, sodium hydroxide, sodium chloride and corrosion inhibitor.

Product of: The Clorox Co., Oakland, CA 94612 Questions? Call 800-292-2200,

Price: 64 fl. oz.

Test Results:

Test A. A sample of gypsum from Station 29 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 46 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There was a distinct lightening in color of the black material while it was in the sample bottle; some of the material was obviously being destroyed. During the entire period the sample was in the solution there were numerous small bubbles on dirty surfaces.

The rinse phase did not appreciably increase the cleansing results. There was very little material on the filter paper. After testing, the gypsum sample had a light yellow-green color resulting from the treatment. This faded with time until after about 7 days the sample was very near the natural color. The product did not produce any other visible speleothem damage. The color is believed to result from the corrosion inhibitor.

Cleansing performance rated VERY GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 3rd most effective product tested in Test B-1, and the 3rd

most effective product tested in Test B-2. The product produced some brown discoloration of the gypsum sample.

Product 19. CO Contact Cleaner

Function: Precision cleaner solvent. Dissolves light contaminants. Evaporates, leaves no residue. Harmless to most plastics, paper tapes, and all metal surfaces. A vapor degreaser. Non-flammable, non-staining, non-corrosive. Authorized by USDA for use in federally inspected meat and poultry plants.

Directions: For best results, use above 60 degrees F. Spray liberally on surface to be cleaned and allow to run off.

Caution: Keep out of reach of children. Use with adequate ventilation.

Contents: None listed

Product of: CRC Chemicals USA, Warminster, PA 18974

Price: 5 oz (aerosol), \$3.65

Test Results:

Test A. A sample of gypsum from Station 29 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then sprayed with the test product. The product was left on the test material for 24 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. The test product appears to break some of the bonding between the black materials and the gypsum. Essentially all cleansing occurs during the rinse phase. Performance rated GOOD.

Product 20. Hydrogen Peroxide

Function: Antiseptic

Directions: Use full strength or diluted.

Caution: Keep out of reach of children.

Contents: Active ingredients: Hydrogen peroxide 3%, Inert ingredients: 97%.

Product of: Topco Associates, Inc. Skokie, IL 60076

Price: 8 fl. oz., \$.57

Test Results:

Test A. A sample of gypsum from Station 29 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 38 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous bubbles on the black coating during the time it was in the hydrogen peroxide solution. Flushing with water yielded a moderate amount of black particles. Performance rated FAIR.

A second test was performed with the same sample. The second time the sample was left in the solution overnight. Performance rated GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 9th most effective product tested in Test B-1, and the 11th most effective product tested in Test B-2.

Product 21. TSP Trisodium Phosphate

Function: All purpose heavy duty cleaner. Removes mildew and mildew stains, greasy, sooty dirt and prepares painted surfaces for repainting.

Directions: Heavy duty cleaning: dissolve 1/2 cup TSP in 2 gallons of hot water. Wring excess cleaner from sponge or mop and wash area. Rinse with clean warm water. Do not allow TSP to stand in puddles. Household cleaning: dissolve 1/4 cup TSP in 2 gallons hot water. Proceed as above. Remove mildew and mildew stains with solution of 1 cup TSP dissolved in 3 quarts of warm water and add 1 quart fresh chlorine bleach. Scrub area thoroughly. The bleach kills fungus growth and removes stain. TSP removes dirt and grime and wets surface so that the bleach can work. Rinse thoroughly with clean, warm water and dry surface completely before painting or hanging wall coverings.

Caution: Do not take internally, avoid contact with eyes and skin. All strong cleaners are irritating to the skin and eyes. Wear rubber gloves; protect eyes and skin from splashes and overhead runs and drips. Wear long sleeve shirt. If swallowed, promptly give 1 or 2 glasses of water or milk and call physician, hospital emergency room or poison control center. Eye contact: flood with plenty of water for at least 15 minutes; get medical attention promptly. Skin contact: wash thoroughly. Keep out of reach of children. Contact with TSP soaked papers or puddles may irritate an animal's foot pads. Hot TSP solutions will darken aluminum containers, and may remove or degloss paints and enamels. Use very weak solution of TSP to clean printed floor coverings. TSP may darken oak, mahogany and some other woods. Try TSP solution in inconspicuous place to be sure results will be satisfactory.

Contents: Trisodium phosphate. Average elemental phosphorous content 7.3% in the form of phosphates. Equivalent to 8.5 grams per 1/2 cup.

Product of: Savogran Company, Norwood, Mass. 02062

Price: 16 oz. (powder), \$1.70

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a concentrated solution of the test product. The product was left on the test material for 36 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. The test product appears to break some of the bonding between the black materials and the gypsum. Performance rated GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 7th most effective product tested in Test B-1, and the 9th most effective product tested in Test B-2.

Product 22. Gunk Tar and Bug Remover

Function: Dissolves road tar spots,...loosens bug deposits, and removes other stains from automobile finishes and chrome. Special formulation prevents fast evaporation and contains holding agents to retard liquid run-off.

Directions: For tar removal: spray liberally on dry surface to be cleaned. Let soak for approximately 30 seconds. Rub away spots with a clean absorbent cloth or sponge that has been pre-saturated with Tar and Bug solution. For bug removal: same as for tar except wiping cloth or sponge should be dampened thoroughly with water prior to saturation with Tar and Bug solution. Rinse surface thoroughly with water after bug deposits are loosened.

Caution: Do not use on hot painted surfaces while exposed to direct sunlight. Pre-test for paint attack on small obscure area on new cars and freshly painted surfaces. Avoid prolonged contact with rubber, plastic and asphalt. Avoid prolonged contact with skin and breathing of vapor or spray mist. If swallowed, do not induce vomiting. Call physician. Use with adequate ventilation.

Contents: None listed

Product of: Radiator Specialty Company, Charlotte, NC 28234

Price: 12 oz. (aerosol), \$1.69

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 15 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

A substantial amount of the black material is removed during the rinse phase. Most of this material is trapped on the filter. The product causes extensive damage to the gypsum. The filtrate looks like skimmed milk as a result of the large amounts of dissolved and suspended gypsum in the solution. The product appears to break some of the bonding between the black materials and the gypsum. Cleansing performance rated GOOD.

Product 23. Gunk Engine Brite

Function: Engine cleaner. Quickly removes grease and grime. A self-emulsifying degreaser.

Directions: Squirt on warm engine. Brush into heavy deposits. Wait 10 to 15 minutes. Hose off. Run engine 15 minutes to dry.

Caution: Apply only to moisture-free surfaces. Rinse over-spray from exterior body surfaces immediately to avoid the possibility of dewaxing or streaking paint. Avoid contact with body paint in hot sun. Do not use on asphalt. Do not use on plastic without testing small area first. Do not use in septic systems. Keep away from heat, sparks or open flame. Avoid prolonged contact with skin. If swallowed, do not induce vomiting. Call doctor. Use with adequate ventilation. Keep from children.

Contents: Contains petroleum distillates.

Product of: Radiator Specialty Company, Charlotte, N.C. 28234

Price: 32 fl. oz., \$2.87

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 19 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product has a very strong petroleum smell. One can immediately note that the product dissolves and otherwise destroys much gypsum. The bottom of the jar was coated with a white layer consisting of damaged gypsum.

The cleansing performance was rated GOOD. This is apparently because of the destruction of the gypsum. All cleansing appears to occur during the rinse phase. This product is one of the most destructive to gypsum of any tested. It is very difficult to remove the product from the sample or from glassware.

Product 24, Original Dupont Formula No. 7 Car Wash Concentrate

Function: Floats off dirt fast. Safe for waxed cars. Cleans car, vinyl top, windows, chrome. Also cleans household walls, woodwork, windows, floors and tile.

Directions: 1/2 capful in a pail of water. Hose off loose dirt from car. Sponge solution on car. Let car drain dry.

Caution: If swallowed, call poison center or physician. Drink plenty of fluids as the product may burn the throat. Vomiting may occur. For eyes, rinse gently and thoroughly with lukewarm water for 15 minutes, pull eyelids gently up and forward to insure rinsing. Keep from children and pets. Not recommended for use in direct rays of hot sun or if finish is hot.

Contents: Contains alkylbenzene sulfonate.

Product of: Borden, Inc. Home and Professional Product Group, Columbus, OH 43215.

Price: 8 oz. (powder), \$2.69.

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a concentrated solution of the test product. The product was left on the test material for 32 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The black material washes off the gypsum very easily during the rinse phase. There may be if there is some minor solutional damage to the gypsum. Cleansing performance rated VERY GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 6th most effective product tested in Test B-1, and the 6th most effective product tested in Test B-2.

Product 25. Driveway Cleaner and Degreaser

Function: Cleans grease, oil, and dirt from blacktop or concrete driveways, lawn mowers, engines, machinery, tools, barbecue grills, and boat bilges. Will not harm blacktop, concrete, iron or steel.

Directions: Shake well. Best when used at 70-90 degrees F. Brush degreaser onto surface. Allow several minutes for cleaner to work, but do not let dry. Scrub into deposits with stiff brush. Hose off. To clean bilge, pour into bilge. Sloshing bilge water will mix with degreaser to clean bilge.

Caution: Do not take internally. Avoid contact with skin and eyes. May cause burns and irritation. Keep away from sparks, heat, and open flame. Do not smoke. Do not operate electrical switches or motors. Turn off pilot lights and other flames. If swallowed, do not induce vomiting. Give large quantities of water, follow with citrus juice or dilute vinegar. Call physician, hospital emergency room or poison center immediately. In case of eye contact flush with plenty of water for at least 15 minutes and get medical attention promptly. For skin contact, wash thoroughly with soap and water. Keep out of reach of children and animals. Wear rubber gloves.

May corrode or discolor soft metals such as aluminum, magnesium, tin plate, galvanize etc. May harm lawns, shrubs, or gardens. Do not allow cleaner to get on belts, pulleys, or brakes.

Contents: Sodium metasilicate, petroleum distillate.

Product of: The Savogran Co., Norwood Mass. 02062

Price: 32 fl. oz., \$3.39

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 35 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The sample was very hard to rinse. A strong petroleum odor remained on the sample after rinsing. The product and the rinse water mixed with it are very messy. It was not possible to assess the extent of gypsum damage, but some damage occurred. The cleansing performance was rated FAIR.

Product 26. B-12 Chemtool

Function: Carburetor choke cleaner. Quickly dissolves gum and varnish from PCV valve, automatic choke, carburetor and linkage, and distributor.

Directions: Simply spray on dirty part.

Caution: Cannot be made non-poisonous. Use only in well-ventilated area, preferable outdoors. Keep away from heat, sparks and open flame. Avoid frequent or prolonged contact with skin. Avoid contact with eyes. In case of contact with eyes, flush thoroughly with water. If swallowed, do not induce vomiting. Call physician immediately. Keep out of reach of children. Removes paint.

Contents: Contains toluene, methyl alcohol, and ethylene glycol monobutyl ether.

Product of: Berryman Products, Inc., Arlington, Texas 76011

Price: 13 oz. (aerosol), \$2.49

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and sprayed with the test product. The product was left on the test material for 32 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product has a strong solvent odor. The product damages gypsum; the filtrate was milky colored from gypsum in solution and suspension. The product also destroys felt marker writing. Cleansing performance rated FAIR to GOOD.

Product 27. Lacquer Thinner

Function: A high solvent-power thinner for lacquer, lacquer type products, and a large variety of epoxy finishes.

Directions: Thinning: follow instructions for thinning on paint product label. Cleaning: for general cleaning or for cleaning synthetic bristle brushes.

Caution: Flammable. Beware of static electricity that may be generated by synthetic clothing and other sources. Use only with adequate ventilation.

Harmful or fatal if swallowed. Do not induce vomiting. Call poison control center, hospital emergency room or physician immediately.

Avoid prolonged or repeated breathing of vapors or spray mist.

Avoid contact with eyes or prolonged contact with skin. May cause irritation. Rinse off skin after use. Flush eyes with water for at least 15 minutes. Keep out of reach of children.

Contents: Contains toluene, methyl ethyl ketone, and methyl isobutyl ketone.

Product of: Klean-Strip, Div. of W.M. Barr, Inc., Memphis, Tenn. 38101

Price: 16 fl. oz., \$1.65

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 38 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product has an extremely strong odor similar to fiberglass resin. Although the product removes an appreciable amount of the black material on the gypsum, it causes some damage to the gypsum. Cleansing performance rated GOOD.

Product 28. Turpex

Function: Paint thinner. Removes wax, grease and dirt. Cleans brushes, rollers, and spray equipment. Cleans hands and removes paint spots.

Directions: Thinning: use only 3/4 part turpex for each part turpentine or other thinner specified on paint can label. Cleaning: clean equipment immediately after using, before they have time to dry.

Caution: Combustible. Avoid breathing of vapor or spray mist. Avoid prolonged contact with skin. Keep out of reach of children. Do not take internally. Use adequate ventilation. If taken internally, do not induce vomiting.

Contents: Petroleum distillate and aromatic hydrocarbon which is a photochemically reactive solvent.

Product of: National Solvent Corporation, Medina, Ohio 44256

Price: 32 fl. oz., \$2.18

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. Essentially all of the cleansing occurs in the rinse phase; this is apparently typical for most solvent compounds. No visible damage to gypsum. Cleansing performance rated GOOD.

Product 29. Strypeeze

Function: Paint and varnish remover

Directions: Best working temperature is 70-85 degrees F. Shake well. Brush remover on in one direction only. Allow enough time for remover to work. Remove with scraper. Wash off remaining residue with brushes or rags using mineral spirits, TSP, or other cleaner in hot water.

Caution: Flammable. Vapors collect in low spots, spread long distances, and may ignite explosively. Before use, shut off power to all electrical outlets, switches, fixtures, motors, furnaces, stoves, heaters, and other appliances. Turn off all flames, pilot lights, electric igniters. Do not smoke or use matches or lighters. Do not restore power or relight flames until all vapors are gone. Vapors contacting flame or hot surfaces may produce gases which are toxic or corrosive to metals.

Cannot be made non-poisonous. Avoid contact with skin or eyes and avoid breathing vapor. Use only with adequate ventilation (moving fresh air ventilation at all levels, particularly at floor level, with all outside doors and windows open). If swallowed, immediately give 1 or 2 glasses of water and call physician, hospital emergency room or poison control center at once for way to induce vomiting. In case of eye contact flood with plenty of water for at least 15 minutes and get medical attention promptly. For skin contact, wash thoroughly with soap and water. Keep out of reach of children. Wear heavy, cotton lined neoprene (not dishwashing) gloves. Protect eyes and skin from splashes. Steel or brass wool or metal objects may spark if they come near other metal.

Contents: Contains acetone, toluol, petroleum distillates, methanol, methylene chloride.

Product of: the Savogran Co., Norwood, Mass 02062

Price: 1 qt., \$4.92

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 37 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product removes much of the black material on the gypsum sample without causing any obvious damage to the gypsum. The product has a very strong odor. A moderate amount of washing is required to remove the product and the black material. The cleansing performance was rated GOOD to VERY GOOD.

Product 30. Pure Gum Turpentine

Function: Paint solvent, thinner, cleaner for brushes, rollers, spray equipment, and trays.

Directions: Follow with a detergent and warm water wash because turpentine leaves a slight gum residue.

Caution: If swallowed, give one or two glasses of water or milk. Call physician immediately. Avoid prolonged breathing of vapor. Avoid contact with eyes or prolonged contact with skin. Keep away from heat and open flame. Use only with adequate ventilation. Keep out of reach of children.

Contents: Turpentine, a pure product derived 100% from pine trees. Photochemically reactive.

Product of: Parks Corporation, Somerset, Mass. 02726

Price: 16 fl. oz.

Test Results:

Test A. A sample of gypsum from Station 9 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. Essentially all material removal occurred during the rinse phase. A noticeable odor remains on the test sample. Cleansing performance rated GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 9th most effective product tested in Test B-1, and the 8th most effective product tested in Test B-2.

Product 31. Window Clean

Function: Cleans mirrors, glass, and porcelain.

Directions: Shake well. Wipe on with sponge. Wipe off before it dries. Polish with soft, dry cloth.

Caution: Do not use on plastic. Keep out of reach of children. Keep from freezing. If swallowed, do not induce vomiting. Seek medical attention immediately.

Contents: Contains petroleum distillate

Product of: Stanley Home Products, Inc., Westfield, MA 01085 24-hour information telephone service 413-527-1000

Price: 22 fl. oz.

Test Results:

Test A. A sample of gypsum from Station 8 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

All removal of black material from the gypsum occurred during the rinse phase. It was extremely hard to remove the purple solution from the gypsum. The solution had a strong odor. Cleansing performance rated GOOD.

Product 32. Sani-Flush

Function: Toilet bowl cleaner. Removes tough hard water stains; tough rust stains and stubborn bowl deposits. It is a strong disinfectant that kills most household germs.

Directions: Wet all surfaces in toilet bowl. Shake 1/2 cup into bowl. Scrub bowl. Wait 10 minutes.

Caution: It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

Do not use on bathtubs, sinks, or any plumbing and septic tanks.

Harmful if swallowed. Damaging to eyes. Irritating to skin. Keep out of reach of children. Do not get in eyes, on skin or clothing. Do not use with chlorine type bleaches, as harmful fumes may result.

If swallowed rinse mouth and give large quantities of milk or water. Do not induce vomiting. Call physician immediately. For external contact, flood surface with water, using soap freely, then cover with moist magnesia or baking soda. If splashed in eyes, wash thoroughly for 15 minutes. Call physician immediately.

Contents: Active ingredients: sodium bisulfate 81%, oxalic acid 1%, Inert ingredients: 18%. Does not contain phosphates.

Product of: Boyle-Midway, Inc., New York, N.Y. 10017

Price: 48 oz.,

Test Results:

Test A. A sample of gypsum from Station 8 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a solution of the test product. The product was left on the test material for 50 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

Some of the black material on the gypsum was destroyed prior to the rinsing phase. The product appears to cause some damage to the gypsum. Cleansing performance rated FAIR to GOOD.

Product 33. Brasso

Function: Cleans and polishes brass, copper, chromium, stainless steel, and pewter.

Directions: Shake well, apply small quantity of Brasso with a clean soft cloth, rubbing lightly to loosen badly discolored areas. Let dry. Polish with a soft, dry cloth.

Caution: Not for use on aluminum, silver, or lacquered finishes. If swallowed, do not induce vomiting. Call physician immediately. In case of contact with eyes, rinse with water for 15 minutes. If irritation persists, contact a physician. Keep out of reach of children. Keep away from heat and flame.

Contents: Contains petroleum distillate and ammonia

Product of: R.T. French Co., Rochester, N.Y. 14609

Price: 7 fl. oz., \$1.55

Test Results:

Test A. A sample of gypsum from Station 8 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 54 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were some black flecks of materials which had been attached to the gypsum present on the filter. All cleansing occurred during the rinse phase. The product turns the gypsum yellow. Cleansing performance rated FAIR.

Product 34. Crystal Drano

Function: All-purpose drain opener. Dissolves grease, food, and hair.

Directions: Remove standing water from sink. Water in drain must be cool. Pour 1 heaping tablespoon (30 gm.) into drain. Add one cup cold water. After 15 minutes, pour cold water down drain. If drain is still clogged, repeat above procedure. Do not repeat after second application. For floor drains, same as above except use 3 heaping tablespoons, and 3 cups of cold water.

Cautions: Causes severe eye and skin damage; may cause blindness. Keep away from eyes, skin, and clothing. Keep from children. Harmful or fatal if swallowed. If contacts eyes, immediately flood with water for at least 20 minutes. Seek medical aid immediately.

If swallowed, give large quantities of milk or water. Do not induce vomiting. Then seek medical aid. If it contacts skin, flood with water for at least 15 minutes. Seek medical aid.

Never use in garbage disposals, dishwashers, toilet bowls or pipes directly connected with such devices. Keep off aluminum utensils, painted surfaces, acrylic and fiberglass bathtubs and basins, and floor coverings.

Never use or mix with other drain cleaners or chemicals before, during or after use as it may react with such products.

Contents: Contains sodium hydroxide (caustic soda-lye). Corrosive. Contains no phosphorus.

Product of: Drackett Products Co., Cincinnati, OHio 45232 Questions? call 1-800-632-1684

Price: 18 oz., \$1.90

Test Results:

Test A. A sample of gypsum from Station 29 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a concentrated solution of the test product. The product was left on the test material for 43 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

Much of the black material which had been attached to the gypsum is removed during the rinse phase. The product alone removes very little material. There is a substantial amount of gritty material in the filtrate which appears to be damaged gypsum. Cleansing performance rated GOOD.

Product 35. Clorox

Function: Bleach, deodorizer and disinfectant. Chlorox is a 5.25% sodium hypochlorite solution; it is a strong oxidizing agent.

Directions: 1 cup in top loading automatic washers. 1/2 cup in toilet bowls. 3/4 cup per gallon water to clean tubs.

Cautions: Causes substantial but temporary eye damage. Do not get in eyes or on clothing. Harmful if swallowed. May irritate skin. Rinse eyes with plenty of water. If swallowed, drink a large quantity of milk or water, get medical aid, avoid alcohol. If skin is contaminated, remove clothing, wash skin.

A strong oxidizing agent, do not use or mix with other household chemicals such as toilet bowl cleaners, rust removers, vinegar, acid, or ammonia containing products. To do so will release hazardous gas. Prolonged contact with metal may cause pitting or discoloration.

Contents: Active ingredient: sodium hypochlorite 5.25%, Inert ingredients: 94.75%. Contains no phosphates.

Product of: The Clorox Co., Oakland, CA 94612.

Price: 1 gallon.

Test Results:

Test A. A sample of gypsum from Station 8 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 41 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The Chlorox immediately begins to lighten the color of the sample. Much of the sample experienced a nearly total removal of the black material which had been attached to the gypsum. Most of the removal is by oxidation; there is not a substantial amount of material on the filter. Rinsing removes particulate matter, dust particles, and a scum. Areas with heaviest black deposition retain a slight greyish color. Cleansing performance rated VERY GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the most effective product tested in Test B-1, and the most effective product tested in Test B-2.

A number of additional tests were conducted with this product, and are discussed elsewhere in this report.

Product 36. Arm and Hammer Super Washing Soda Detergent Booster

Function: Whitens, brightens, and removes greasy dirt from clothes. Deodorizes. Replaces bleach. All purpose cleaner for the household. Sudsless.

Directions: 1/2 cup to washing machine. 1/2 cup per bucket warm water as household cleaner.

Caution: Not recommended for aluminum surfaces as it may cause discoloration. Avoid contact with eyes. If contact made, flush with water. If swallowed, give water or milk. Contact a physician. Keep from children. May be harmful if swallowed.

Contents: Contains no phosphates.

Product of: Arm and Hammer Div. of Church and Dwight Co., Inc., 20 Kingsbridge Road, Piscataway, N.J. 08854

Price: 55 oz., \$1.59

Test Results:

Test A. A sample of gypsum from Station 21 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a concentrated solution of the test product. The product was left on the test material for 54 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product removed very little of the black material which was attached to the gypsum sample. Cleansing performance rated INEFFECTIVE.

Product 37. Wisk

Function: Heavy duty laundry detergent. Use 1/2 cup for normal laundry loads.

Caution: Keep from children. In case of eye contact, flush well with water and call a physician.

Contents: Cleaning agents (anionic and nonionic surfactants), water softener (sodium citrate), stabilizer, buffering agent, perfume, brightening agents, opacifier, and colorants. Does not contain phosphorous. The surfactants are biodegradable.

Product of: Lever Brothers Company, New York, N.Y. 10022 Questions? Call 1-800-544-2002

Price: 64 fl. oz.

Test Results:

Test A. A sample of gypsum from Station 21 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product; the product was not diluted in this test. The product was left on the test sample for 33 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

It was extremely difficult to cleanse the sample and remove the "soapy" material. The product did not remove much of the black material attached to the gypsum; the rinse phase was also not very effective. Cleansing performance rated FAIR.

Product 38. White distilled vinegar.

Function: For food and cleansing purposes.

Caution: None listed.

Contents: Apple vinegar reduced with water to 5% acidity. Acetic acid.

Product of: Arkansas Vinegar Co., Rogers, AR 72756.

Price: 1 gallon.

Test Results:

Test A. A sample of gypsum from Station 30 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 20 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. The test product appears to dissolve some of the bonding between the black materials and the gypsum. Vinegar may be most useful in cleanup work after treatment with other agents. Cleansing performance rated FAIR to GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 2nd most effective product tested in Test B-1, and the 5th most effective product tested in Test B-2.

Product 39, Water

Test Results:

Test A. A sample of gypsum from Station 21 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with well water. The sample was left in the bottle for 33 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. Most of the cleansing occurred during the rinse phase. Cleansing performance rated FAIR.

Product 40. Simple Green

Function: A concentrated industrial strength cleaner and degreaser.

Contents: A coldwater activated biodegradable non-toxic and non-flammable compound. Authorized by USDA for use in federally inspected meat and poultry plants. A wetting agent rather than an abrasive.

Product of: Sunshine Makers, Inc., P.O. Box 467, Sunset Beach, CA 94742. Specify part #13005.

Test Results:

Test A. A sample of gypsum from Station 21 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 39 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product removed some black flecks of materials which had been attached to the gypsum. The product was very "soapy" and difficult to remove from the gypsum. Cleansing performance rated FAIR to GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 9th most effective product tested in Test B-1, and the 10th most effective product tested in Test B-2.

Product 41. Saturated solution of potassium hydroxide in 70% isopropyl alcohol.

Function: A strong base solution mixed for the purposes of this study.

Test Results:

Test A. A sample of gypsum from Station 29 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were numerous black flecks of materials which had been attached to the gypsum present on the filter. Most of the cleansing occurs during the rinse phase; very little occurs with only the potassium hydroxide and alcohol solution. No visible damage to the gypsum. Cleansing performance rated GOOD.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 11th most effective product tested in Test B-1, and the 7th most effective product tested in Test B-2.

Product 42, 37% Formaldehyde

Function: General-purpose preservative

Caution: For laboratory use only. Not for drug use.

Causes irritation of skin, eyes, nose, and throat. May be fatal if swallowed. May cause skin sensitization.

Keep out of reach of children. Avoid prolonged breathing of vapor. Use with adequate ventilation. In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes; for eyes, get medical attention.

First aid--antidote: Give tap water, milk, or milk of magnesia. Give whites of eggs beaten with water. Call a physician. Do not store at temperatures below 13 degrees C. Polymerization may occur.

Contents: Formaldehyde, 37%

Product of: Fisher Scientific Co., Fair Lawn, NJ

Price: 1 pint

Test results:

Test A. A sample of gypsum from Station 30 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

There were black particles on the filter. Most of these were removed during the rinse. Cleansing performance rated INEFFECTIVE.

Product 43. Tinactin Antifungal Powder

Function: Kills athlete's foot and jock itch fungi.

Directions: Sprinkle powder liberally on all areas of infection and in shoes or socks. To help prevent recurrence of athlete's foot or jock itch, bathe daily, dry carefully, and apply Tinactin powder.

Caution: For external use only. Do not use Tinactin powder on scalp. If irritation occurs, discontinue use and consult your physician or podiatrist. Keep out of eyes.

Keep this and all drugs out of the reach of children. In case of accidental ingestion, seek professional assistance or contact a poison control center immediately.

Contents: Tolnaftate 1%

Product by: Schering Corp., Kenilworth, NJ 07033

Price: 1.5 oz.

Test Results:

Test A. A sample of gypsim from Station 21 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a concentrated solution of the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product removed little or none of the black material which was attached to the gypsim sample. Cleansing performance rated INNEFFECTIVE.

Product 44, Quinsana Foot Powder

Function: For athlete's foot and daily foot care.

Directions: Use morning and night for painless relief of maddening itch and burning sensation caused by athlete's foot.

Caution: If condition or infection persists, consult your podiatrist or physician. Keep out of children's reach.

Contents: Hydroxy-quinoline sulfate, boric acid.

Product of: Mennen Co., Morristown, NJ 07960

Price: 3 oz.

Test Results:

Test A. A sample of gypsum from Station 21 (a ledge above the water fountain in the Snowball Dining Room) was used. The sample was placed in a screw cap bottle, and then covered with a concentrated solution of the test product. The product was left on the test material for 42 minutes, then poured through filter paper. The sample was then rinsed with clean water from a spray bottle.

The product removed little or none of the black material which was attached to the gypsum sample. Cleansing performance rated INEFFECTIVE.

Product 45. Clorox and TSP Trisodium Phosphate

Function: Clorox kills fungus growth and removes stain. TSP removes dirt and grime and wets surface so that Clorox can work.

Directions: See individual products.

Caution: See individual products.

Contents: See individual products.

Product of: See individual products.

Price: See individual products.

Test results:

Test A: Not subjected to test A.

Test B. This product was one of 11 products subjected to Standard Test B. The procedure is discussed on page 36.

This product was the 5th most effective product tested in Test B-1, and the 4th most effective product tested in Test B-2.

Field Testing of Methods for Removing Unnatural Coatings

On June 17, 1986 we visited the Snowball Dining Room to conduct some brief field testing of methods for removing the unnatural coatings. Our visit was made during a period when the dining room was in operation and tours were using the Snowball Dining Room.

Nine small wall and ceiling areas were selected for the field testing. The testing consisted of lightly applying a 5.25% sodium hypochlorite solution to an area of approximately one square foot. The application was made as a mist spray from a plastic spray bottle. The treated surface was merely moistened with the spray.

The treated areas were periodically examined over periods ranging from 20 minutes to two hours. Treated areas were rinsed with a water spray from a plastic spray bottle after the sodium hypochlorite had been given 10 to 20 minutes to act on the unnatural coatings. The rinse water was from the water fountain in the Snowball Dining Room.

The areas selected for field testing were as follows:

Site 1. A gypsum coated wall and ceiling area near the water fountain. The unnatural coating was moderately heavy. The ceiling was similar in composition and appearance to the "snowball" ceilings in the Snowball Dining Room.

Site 2. An area near Site 1. The wall surfaces were similar to Site 1, but the unnatural coating was heavier.

Site 3. A blackened gypsum ceiling area inside the men's restroom.

Site 4. A gypsum crystal area outside the men's restroom. The selected area was apparently outside the normal airflow pattern from the restroom; the gypsum appeared to have little unnatural discoloration.

Site 5. A small gypsum ceiling area behind the freezer area in the Snowball Dining Room.

Site 6. A wall area on the side of a loop passage across the main passage from the freezer area. This side passage contains extensive black coatings in addition to some white coatings which appear to be the result of bacterial or fungal activity; neither the black or white coatings are natural to this passage.

Site 7. A wall area adjacent to the dining portion of the Snowball Dining Room. The name "Ken" has been written on the wall in pencil; it appears to be of relatively recent vintage. The wall had some of the white coating noted above at Site 6.

Site 8. A blackened ceiling area near a light fixture about 200 feet from that end of the Snowball Dining Room which is furthest removed from the food serving area.

Site 9. An area of black-coated gypsum along a former tour route in Specimen Avenue.

Our field testing was neither designed nor intended to be a standard type of testing. Instead, our field work was intended to provide insight into a number of questions of management significance. These questions, and our findings, are discussed in the following paragraphs.

Our field testing indicated that a 5.25% sodium hypochlorite solution, when applied as a mist, will rapidly destroy much of the unnatural coatings in the Snowball Dining Room. Our field test results were similar to our laboratory test results.

Our field testing suggests that a quart of water will rinse on the order of 3 to 10 square feet of cave surface after sodium hypochlorite treatment. Plastic sheets will probably be desirable for collecting the used rinse water. Perhaps a wet vacume could be used in those areas with a concrete floor.

Dramatic cleansing results were noted at Sites 1, 2, and 8. It seems likely that most of the unnatural coatings at these sites would be removed by two applications of 5.25% sodium hypochlorite and two water rinses.

Site 6 had the most extensive unnatural coatings of any of the field test sites. The sodium hypochlorite treatment worked extremely well at this site; it removed both the black coating and the unnatural white coating. One application provided an almost total restoration of the natural surfaces.

The unnatural white coating at Site 7 was also totally, or almost totally, removed. The treatment did not appear to remove any of the pencil marks.

The unnatural black coating at Site 5 was partially cleaned by one application of 5.25% sodium hypochlorite. However, the cleansing performance at this site was not as good as at Sites 1, 2, 6, 7, and 8.

The sodium hypochlorite treatment at Sites 3 and 9 did not have any noticeable impacts on the black coatings. One possible explanation is that fungal or bacterial growth in association with the coatings is necessary or at least helpful if the coatings are to be removed. Site 3 may lack such fungal or bacterial growths because of disinfecting agents used in the restroom. Site 9 may lack such fungal or bacterial growths because of lower relative humidities or other unidentified factors.

The testing at Site 4 did not have any detectable impacts on the color or appearance of the test site. This is a field confirmation of our laboratory observation that the 5.25% sodium hypochlorite solution does not alter the natural coloration of limestone, gypsum, or calcite speleothems.

A Preliminary Cave Restoration Approach

We have developed a preliminary restoration approach for restoring near-natural integrity to wall and ceiling surfaces in the Snowball Dining Room of Mammoth Cave. The approach is based upon the results of our investigations, past experience in cave restoration work, and information from the technical literature.

The gypsum speleothems are very fragile. As a result, they cannot be physically scrubbed. They are also subject to damage from anything more than relatively low water pressures. These conditions dramatically limit potential cleansing approaches.

Bleach (5.25% sodium hypochlorite solution) is the most effective agent for destroying or removing the unnatural coating from surfaces in the Snowball Dining Room. Bleach is an oxidizing agent. It works by actually destroying much of the unnatural material which adheres to the cave surfaces.

The unnatural coating in the Snowball Dining Room is commonly "sticky". Dust particles, fragments of gypsum, and lint adhere to (and are a part of) the coating. Most of these materials are unaffected by the bleach. Because of this, they tend to protect underlying portions of the coating from effective oxidation by the bleach. The dust particles, fragments of gypsum, and lint can generally be removed by the alternating bleach applications with applications of a low pressure mist of water. Household spray bottles produce a mist which does an adequate job without causing physical damage from excessive water pressure.

In places there are pockets within the gypsum crust which have trapped substantial amounts of unnatural debris. These pockets can be cleaned through the careful use of a "Water Pik," operated at low to moderate pressure settings. This device is designed for cleaning around teeth and dentures; it does a good job on pockets in the gypsum. The Water Pik should be used only with water, and only in localized areas.

Our laboratory experiments suggest that about 95% of the unnatural coating on gypsum and limestone surfaces can be removed by the following procedure:

1. Apply a mist of bleach (5.25% sodium hypochlorite) to the area to be treated. Leave undisturbed for a period of at least 12 hours. It can be left undisturbed for a few days if this is needed for convenience. The application rate should moisten the surface. Some drippage or runoff will occur, but it should be kept to a minimum.

2. Rinse with a mist of water to flush off dust and lint. Water pressures must be kept low to prevent physical breakage of gypsum speleothems. Water application rates should be kept as low as possible. Initially household spray bottles should be used. Ultimately, larger spray units might be usable if application pressures are kept low enough to prevent any breakage.

3. Repeat the bleach and rinse cycle as necessary. Most areas will probably require two to three treatments.

4. Use a "Water Pik" to clean localized pockets in the gypsum.

5. There may be some localized situations where the application of some vinegar may be necessary. The vinegar operates by dissolving the contact between an attached material and underlying gypsum. Vinegar may locally be needed as a final "touch-up" agent. Its use should be restricted to spots where unnatural coatings cannot be removed by oxidation or flushed away by water. Any vinegar should be applied with a small spray bottle. Caution! No vinegar may be used until at least 48 hours after the last bleach use in the cave chamber. No bleach odors may remain at the time of treatment. The reason is that mixing acids, such as vinegar, with bleach may release poisonous chlorine gas.

6. Our field testing indicated that the 5.25% sodium hypochlorite treatment is not uniformly effective in all areas. Specific strategies will need to be developed for some of the problem sites.

Protection of the Cave

Four mil plastic sheets without holes should be placed on natural cave surfaces beneath areas being treated. The sheets should be arranged to facilitate the collection of liquids which drip or run from cave surfaces. It is desirable to catch and remove as much of the liquids from the cave as possible. In areas where liquids cannot be collected, the liquids should not be diluted by adding excess water.

We have conducted extensive plant growth studies in Blanchard Springs Caverns, Arkansas; Carlsbad Caverns, New Mexico, and Oregon Caves, Oregon. These studies have demonstrated that 5.25% sodium hypochlorite solutions appear to be ideal for work in caves. We anticipate that weaker solutions would be less effective, and would actually result in heavier application rates to attain the same results. Based upon our tests to date, we do not believe that stronger sodium hypochlorite solutions are needed.

Calcium hypochlorite solutions should not be used. Calcium hypochlorite is not as strong an oxidizing agent as is sodium hypochlorite. As a result, more calcium hypochlorite must be applied to attain results comparable to those with sodium hypochlorite. Finally, calcium hypochlorite applications in Carlsbad Caverns (Aley and Aley, 1984) resulted in unnatural calcium chloride deposits on speleothems.

The use of bleach will create unnatural odors in the cave. The odors will decrease over a period of a few hours to a day or so. Small applications on several days is a better approach than a large application on a single day. Use of bleach in controlling plant growth in other National Park Service and private show caves has been accomplished with negligible problems and minor inconvenience. Most (and probably all) problems can be minimized and prevented by a good treatment protocol and good training and supervision of workers.

Protection of Workers

Bleach is a strong oxidizing agent and must be used with care. Bleach can seriously injure lungs, eyes, and other sensitive human tissue. For safety, workers must use respirators appropriate for chlorine gas environments, and must wear goggles. Additionally, appropriate rubber gloves and clothing should be worn.

Worker safety can be insured by a good treatment protocol and by good training and supervision of workers. Additionally, safety equipment such as respirators and goggles must be both effective and comfortable. It has been our experience that some of the less expensive respirators and goggles are extremely uncomfortable for extended use. Uncomfortable or awkward safety equipment provides an unwarranted incentive for workers to dispense with the equipment.

Findings and Conclusions

1. The unnatural coatings on gypsum and limestone surfaces in the Snowball Dining Room are typically grey to black in color. There are numerous soil or dust particles which adhere either to the cave surfaces or to the unnatural coatings on these surfaces. The dust or soil particles typically comprise about 10 to 50% of the foreign materials coating cave surfaces.

2. Based upon microscopic observations, it is our finding that the cohesive black material which coats many of the surfaces in the Snowball Dining Room is largely derived from cooking and heating foods. However, food preparation may not be the only important source of the black deposits.

3. Microscopic observations of some samples from the Snowball Dining Room also disclosed the presence of fungal mycelium. The extent of fungal growth on the gypsum is difficult to quantify; there is no reason to believe that it is only in the form of mycelium. Bacterial growths may also be a component of unnatural wall coatings in the Snowball Dining Room.

4. During the summer use season in the Snowball Dining Room there are routine daily increases in both air temperature and relative humidity in the Snowball Dining Room.

5. Temperatures in the Snowball Dining Room typically begin to increase at about 10:00 AM, and will increase noticeably until about 12:30 PM. They then increase more slowly until reaching a peak at about 4:00 PM. Temperatures then decrease at a fairly steady rate until about 7:30 PM when they have returned to about the same temperature as existed prior to 10:00 AM. The mean temperature increase associated with the daily cycles is about 0.9 degrees F.; daily increases vary from 0.5 to 1.5 degrees F.

6. Relative humidity values in the Snowball Dining Room also show a daily cycle during summer. Relative humidity begins to increase at about 9:45 AM, and increases within 15 minutes to an hour to a new and fairly constant value. The increased relative humidity persists until about 2:30 PM; it then declines until about 4:00 PM when it has returned to about the same value as existed prior to 9:45 AM. The mean increase in relative humidity associated with the daily cycles is 1.5%; increases range from 0.5 to 2.0%.

7. The almost daily increases in temperature and relative humidity in the Snowball Dining Room reflect use of this chamber. Temperature increases are caused by the electric lights, cooking and heating elements, and by body heat from visitors and employees. Some temperature increases may also be associated with the introduction of water into and through the restroom facilities. Relative humidity increases are probably due primarily to steam from hot food; human respiration may also be involved.

8. The routine daily temperature increases are important in transporting grease

and other particles upward toward the ceiling in the Snowball Dining Room. At some times increased temperatures and relative humidities in the air of the Snowball Dining Room may be sufficient to cause some condensation on cave surfaces, which in turn may increase the number of particles which become attached to the cave ceiling.

9. Filtration of large volumes of air disclosed that substantial quantities of black material are suspended in the air of the Snowball Dining Room. This occurs even during times of low visitation. The black material is believed to be primarily carbon compounds.

10. Variations in the amount of black material found in the air filters suggests that some non-continuous processes are important in introducing the black material into the air or in keeping it suspended in the air. Air velocities through the cave passages could be a very important factor. Similarly, fluctuations in air temperature and relative humidity could be implicated in the introduction of the black material into the air from cave surfaces.

11. A total of 44 potential cleansing agents were selected for laboratory study. These agents included acids, bases, solvents, reducing agents, oxidizing agents, detergents, sequesterants, surfactants, degreasers, and biocides.

12. The laboratory studies on gypsum samples from the Snowball Dining Room and vicinity indicated the following cleansing potential for various groups of cleansing agents. Oxidizing agents are best; they are better than strong bases, which in turn appear to be substantially better than any other types of agents. Strong bases are better than acids; acids are similar in performance to degreasers and solvents, which in turn are better than surfactants, sequesterants, and detergents. Biocides and reducing agents are the least effective in removing the unnatural black coatings from the gypsum.

13. A number of the tested cleansing agents have potential problems which would limit or prevent their use in the Snowball Dining Room. Some of the cleansing agents are difficult to remove from the gypsum, some damage the gypsum, some create fumes, and some have general toxicity problems. The potential problems for various products are summarized in Table 6.

14. Based upon laboratory and field tests, the most promising cleansing agent is 5.25% sodium hypochlorite (bleach). It works by oxidizing (and thus destroying) the unnatural coatings.

15. Applications of 5.25% sodium hypochlorite solutions are followed by water rinses. Vinegar may be useful in some problem areas.

16. Our laboratory experiments suggest that about 95% of the unnatural coating on gypsum and limestone surfaces can be removed by a procedure outlined in the section of this report entitled "A Preliminary Cave Restoration Approach". The approach uses 5.25% sodium hypochlorite solutions and water rinses. Steps for protecting the cave and workers are briefly identified.

Need for Phase II Investigation

Resolving the problem of the unnatural coatings in the Snowball Dining Room was initially viewed as a two phase project. Phase I was to determine if there appeared to be a methodology for removing the unnatural coatings. If Phase I was successful, then Phase II was to put the system into operation.

Our Phase I studies have been completed. They have been extremely successful, and we have found a methodology which offers tremendous potential for the restoration of the Snowball Dining Room as well as other relevant portions of Mammoth Cave.

Phase II investigations should begin and continue through the winter of 1986-1987. The investigations should include the following tasks:

Task 1. Study potential problems, limitations, and adverse impacts of restoration techniques which appear useful.

This work will involve the following 4 sub-tasks:

1. Specific literature review of treatment agents.
2. Additional field and laboratory testing as warranted. For logistical reasons this may involve testing in Tumbling Creek Cave at the Ozark Underground Laboratory. The impacts of repeated treatments is an issue which might require additional testing in Tumbling Creek Cave.
3. Identify and lab-test mitigating procedures.
4. Select recommended techniques and relevant equipment.

Task 2. Final field tests.

The field tests will be conducted in the Snowball Dining Room, and will be designed to "work out the bugs" in the recommended techniques. The work will be done during the winter to minimize conflicts with cave visitation.

Field testing conducted during Phase I investigations indicated that techniques may need to be adjusted and tailored to different conditions. During the field tests we will select, in cooperation with the National Park Service, a range of sites within the Snowball Dining Room for detailed testing. Field testing work will be thoroughly documented.

The field tests will be a time for National Park Service personnel to become familiar with the recommended techniques and their applications. Familiarization and training of National Park Service personnel in the recommended techniques is viewed

as a necessary and integral part of this task. It is our expectation that the restoration techniques which are developed can be readily used by National Park Service personnel who are likely to be assigned to restoration work.

Task 3. Assessment of all developed portions of Mammoth Cave to determine areas where restoration work is warranted.

As a result of experience gained in Phase I studies and the previously identified tasks, we will be uniquely qualified to make this type of assessment. Such an assessment is needed for natural resource management and planning purposes.

It is possible that areas can be ranked according to the urgency of restoration work and/or the magnitude of resource restoration which is attainable. Such a ranking will be done if it appears appropriate.

We will identify modifications of techniques which may be needed for localized situations. Some techniques may need to be excluded from certain areas or situations.

Task 4. Develop management recommendations for preventing or minimizing future development of unnatural coatings on cave surfaces in Mammoth Cave.

This work will include the following four sub-tasks:

1. Develop a history of use in Mammoth Cave useful in characterizing the nature and extent of activities which may be associated with the unnatural coatings in the cave. This will be based largely on field interviews of people with long familiarity with the cave and upon use records where such records exist.

2. With National Park Service cooperation in the collection of air filters, we will examine filters collected from various parts of the cave and from sites outside of the cave. This will increase our understanding of the sources and movement of carbon compounds within Mammoth Cave.

3. Identify and evaluate all use and management activities which appear to be associated with unnatural coatings in Mammoth Cave.

4. Develop specific management recommendations.

Task 5. Report.

We anticipate the preparation of 15 copies of the final report. A draft copy (or copies) will be submitted for review. The report will detail all work conducted in the study.

Additionally, the report will include detailed and specific management recommendations for restoration work in Mammoth Cave. Furthermore, the report will detail specific management recommendations for preventing or minimizing similar restoration needs in the future.

Management Recommendations

This study was planned as a two phase investigation. Phase I, which this report details, was designed to identify potentially useful restoration techniques for removing unnatural coatings from cave surfaces in the Snowball Dining Room. Such techniques have been discovered, and they look very promising.

Phase II investigations, which are outlined in the previous section, will lead to the actual restoration of the Snowball Dining Room. Additionally, these investigations will include an assessment of all developed portions of Mammoth Cave to determine areas where restoration work is warranted. Finally, Phase II investigations will include the development of management recommendations for preventing or minimizing future unnatural coatings on cave surfaces.

Recommendation 1. We recommend that the Phase II of the Snowball Dining Room restoration study be funded so that the essential work can be done during the winter of 1986-1987.

Use practices and management activities which introduce carbon compounds into the cave air create serious detrimental impacts on the cave. Identification and characterization of these practices and activities will be conducted during Phase II investigations. In the meantime, members of the Park staff and others should be made aware of the nature of the problem.

Recommendation 2. It is possible that some simple changes could be made which would have significant benefits in the reduction of carbon compounds in the cave air. One logical change which should be considered at this time would be the end of torch throwing in the cave.

Recommendation 3. Results to date make it clear that a program of reducing carbon compounds (and perhaps also water vapor) in the air of the Snowball Dining Room will be needed. These management improvements are necessary for the protection of cave features. This may be a good time to begin consideration of potentially viable options for reducing the problems in this area of the cave. The adequacy of potential options could be evaluated during Phase II investigations.

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APPENDIX A

Explanation for determining colors according to the Munsell System (Munsell Color Corp., 1975).

DETERMINATION OF SOIL COLOR

quoted in part from

U.S. Dept. Agriculture Handbook 18—Soil Survey Manual

Soil colors are most conveniently measured by comparison with a color chart. The collection of charts generally used with soils is a modified version of the collection appearing in the Munsell Book of Color and includes only that portion needed for soils, about one-fifth of the entire range found in the complete edition.

The seven charts in the Soil Collection display 199 different standard color chips systematically arranged according to their Munsell notations, on cards carried in a loose leaf notebook. The arrangement is by the three simple variables that combine to describe all colors and are known in the Munsell system as Hue, Value, and Chroma.

The Hue notation of a color indicates its relation to Red, Yellow, Green, Blue, and Purple; the Value notation indicates its lightness; and the Chroma notation indicates its strength (or departure from a neutral of the same lightness).

The colors displayed on the individual Soil Color Charts are of constant Hue, designated by a symbol in the upper right-hand corner of the card. Vertically, the colors become successively lighter from the bottom of the card to the top by visually equal steps; their value increases. Horizontally they increase in Chroma to the right and become grayer to the left. The Value notation of each chip is indicated by the vertical scale in the far left column of the chart. The Chroma notation is indicated by the horizontal scale across the bottom of the chart.

As arranged in the collection the charts provide three scales: (1) radial, or from one chart to the next in hue; (2) vertical in value; and (3) horizontal in chroma.

"The nomenclature for soil color consists of two complementary systems: (1) Color names, and (2) the Munsell notation of color. Neither of these alone is adequate for all purposes. The color names are employed

in all descriptions for publication and for general use. The Munsell notation is used to supplement the color names wherever greater precision is needed, as a convenient abbreviation in field descriptions, for expression of the specific relations between colors, and for statistical treatment of color data. The Munsell notation is especially useful for international correlation, since no translation of color names is needed. The names for soil colors are common terms now so defined as to obtain uniformity and yet accord, as nearly as possible, with past usage by soil scientists. Bizarre names like 'rusty brown,' 'mouse gray,' 'lemon yellow,' and 'chocolate brown' should never be used."

The soil color names and their limits are given in the diagrams which appear opposite each chart.

"The Munsell notation for color consists of separate notations for hue, value, and chroma, which are combined in that order to form the color designation. The symbol for hue is the letter abbreviation of the color of the rainbow (R for red, YR for yellow-red, Y for yellow) preceded by numbers from 0 to 10. Within each letter range, the hue becomes more yellow and less red as the numbers increase. The middle of the letter range is at 5; the zero point coincides with the 10 point of the next redder hue. Thus 5YR is in the middle of the yellow-red hue, which extends from 10R (zero YR) to 10YR (zero Y)."

"The notation for value consists of numbers from 0, for absolute black, to 10, for absolute white. Thus a color of value 5/ is visually midway between absolute white and absolute black. One of value 6/ is slightly less dark, 60 percent of the way from black to white, and midway between values of 5/ and 7/."

"The notation for chroma consists of numbers beginning at 0 for neutral grays and increasing at equal intervals to a maximum of about 20, which is never really approached in soil. For absolute achromatic colors (pure grays, white, and black), which have zero chroma and no hue, the letter N (neutral) takes the place of a hue designation."

"While important details should be given, long involved designation of color should generally be avoided, especially with variegated or mottled colors. In these, only the extreme or dominant colors need be stated. Similarly, in giving the color names and Munsell notations for both the dry and moist colors, an abbreviated form, such as 'reddish brown' (5YR 4/4; 3/4 moist), simplifies the statement."

"By attempting detail beyond the allowable accuracy of field observations and sample selection, one may easily make poorer soil descriptions than by expressing the dominant colors simply. In all descriptions, terms other than the ones given on these charts should be used only in rare instances, and then only as supplemental expressions in parentheses where some different local usage is common."

"The ability to sense color differences varies among people, even among those not regarded as color blind." The Farnsworth-Munsell 100 Hue Test, available from Munsell Color, is a dual-purpose test which examines subject for color anomalies and at the same time grades color normals on their color aptitude.

In the 1975 Edition, the darkest value shown is 2/ on the 7.5YR through 2.5Y charts and 2.5/ on all others. Low value, high chroma colors added to the 7.5YR and 10YR chart, outside the matte pigment gamut, are necessarily produced in glossy finish. This collection contains the seven charts (10R, 2.5YR, 5YR, 7.5YR, 10YR, 2.5Y, and 5Y) used by the U. S. Soil Conservation Service. The following supplementary charts are available:

7.5R—slightly more red than 10R, used in most tropical and semi-tropical lands.

5R —slightly more red than 7.5R, used in tropical lands, particularly Australia, Africa and South-east Asia.

/1 Chroma—a selection of near-gray colors for hues from yellow through green and blue, for submerged soils, 28 colors on value levels 4/ through 7/.

APPENDIX B

Project Photographs

Photo 1 (top). Samples treated with 11 different products (numbers on photograph are the same as identification numbers in the text). Untreated sample for comparison.

Photo 2 (bottom). Samples treated with the five most promising agents. The samples are the same as those in Photo 1. 5.25% sodium hypochlorite solution (bleach) is Product #35.

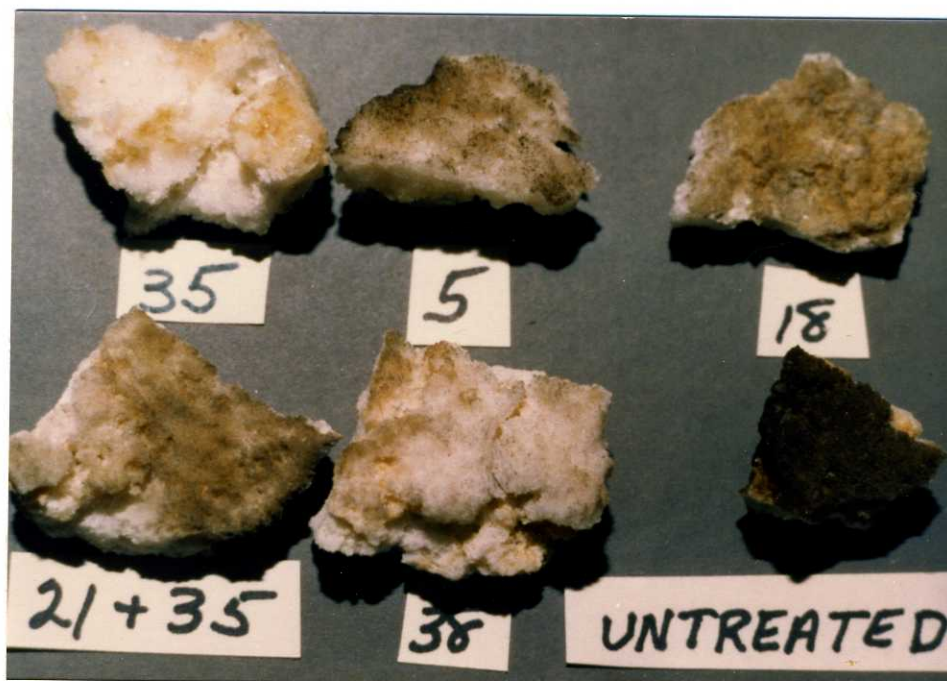


Photo 3 (top). Sample treated twice with bleach and rinsed twice with water. The treated sample is a piece of the material in the background; note the dramatic improvement.

Photo 4 (bottom). 12 air filters. The upper left sample is a blank. The filter to the right of it is from the vicinity of the TB huts. All other samples are from the Snowball Dining Room; the order is in decreasing concentration of visible discoloration due to trapped particulate matter.



Photo 5 (top). Sample of delicate gypsum crust which had been held in the smoke from a burning cotton rag which was soaked in kerosene.

Photo 6 (bottom). Same sample as in Photo 5 after two treatments with 5.25% sodium hypochlorite and two rinses.

