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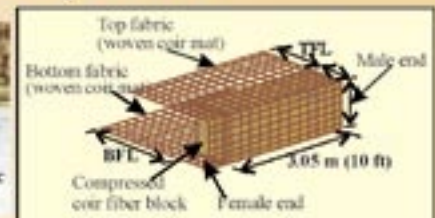
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Educate and Inform – It's Only Natural!

This year ASMR members had an opportunity to attend two ASMR co-sponsored meetings: St. Louis in March and Billings in June. I always enjoy reconnecting with friends and ASMR acquaintances at our meetings. In my university job, I am pulled in many directions, but while at the meeting, I am a full time reclamation scientist. It is a great venue for technology transfer and recharging our reclamation batteries. A highlight for me at the Billings meeting was Montana Governor Brian Schweitzer's talk at the plenary session when I discovered he was a fellow soil scientist, or at least he had a master of science degree in soil science. With the governor as an example, there may be some hope for interesting careers for my MS students, even if they do not go directly into the exciting fields of soil science or reclamation.

Mining and associated activities often receive bad press. For example, in the University of Illinois student paper last year there was a series of letters to the editor about mountain top removal in the Appalachians. The writers did not really understand the issues, but were against it, based on an emotional argument. Also, opposition to longwall mining has recently risen in Illinois because of proposed new longwall mines, and again the opposition is largely based on emotional and not scientific or technical grounds. Although emotion will always have some influence on decision makers, accurate, unbiased information is something that ASMR and its members should provide the public so modern reclamation science and technology enters into the decision making process. We, in the natural resource business—broadly defined here as the production of goods and services associated with the use and management of minerals and materials—have an obligation to educate and inform the public about our work. Unfortunately, public perception

is often based on the “bad old days” before reclamation was widespread or effectively applied.

Modern reclamation really started with the federal Surface Mining Control and Reclamation Act of 1977, but the awareness that there was more to mining than simply walking away from the site after the material of interest was extracted, is older than that. I recently watched an old movie—“The Treasure of the Sierra Madre”—that I had seen many years ago. It was made in 1948 and is an enjoyable, well-done movie, and on most lists of the best movies ever made. It is about greed and the effect newfound wealth can have on individuals.

We, in the natural resource business—broadly defined here as the production of goods and services associated with the use and management of minerals and materials—have an obligation to educate and inform the public about our work.

Many people are familiar with the bandit's “We don't need any stinking badges!” quote, but there is another quote from the movie that really impressed me on my recent viewing. It is an exchange between the wise old-timer, Howard, and the greenhorns Dobbs and Curtin, after they finish their gold mining and are about to leave the site:

Howard: “It'll take another week to break down the mine and put the mountain back in

shape. Make 'er appear like she was before we came. We've wounded this mountain and it's our duty to close her wounds. It's the least we can do to show our gratitude for all the wealth she's given us. If you guys don't want to help me, I'll do it alone.”

Here is the sentiment all true reclamationists feel. We all want to “put the mountain back in shape.” In the movie, the reclamation work does not get the same attention as the actual gold mining, but you know they probably did a good job of it. In real life, it takes hard work, based on the experience, research, equipment, and materials that ASMR members provide to show our gratitude for all the wealth the earth has given to us. ■



Open Your Mind!

A colleague and I were recently discussing the numerous and disparate voices that are heard on various environmental issues. Some voices cry out that the world is rapidly coming to an end based on the latest information on global warming, ozone thinning, nuclear waste, water pollution, over-population, or infectious diseases. Other voices counter that there are no environmental catastrophes and that all these crises are overblown. Most of us quietly read or listen to the voices of the so-called experts and either dismiss or embrace their opinions based on our own biases. As informed and honest scientists, however, we continually wonder whether we have reached the correct conclusion. So, we question our position on these subjects and we search high and low for new data from a variety of sources to add to our knowledge. We decide which sources are credible, carefully read their results and interpretations, and try to synthesize and balance the information into a coherent and rational set of statements that

establishes—and sometimes refines—our feelings on the subject.

The problem with most of the persistent environmental conflicts is that the data do not give conclusive evidence and do not directly point out answers, or trends, for an issue. In fact, for many of these complex issues, prognosticators come to completely opposite interpretations using the same data! And this is the very reason why we hear so many conflicting voices, because the data and interpretations are not clear about causal relationships.

My friend then mentioned something he had learned long ago that provides insight here: “A person is entitled to his own opinion, but not to his own facts!” Much of the contention and confusion surrounding environmental conflicts are centered in the way that some people use only the data or facts that support their position and ignore any contrary or opposing facts. The breakdown occurs when a person does not use all the facts, and hence becomes closed-minded.

Ultimately, the responsibility for gathering facts about complex issues and reaching an educated opinion rests with each individual. Re-adjusting and refining a stance on any particular subject is an ongoing process, and contingent upon securing sound, up-to-date information.

In reclamation science, we are largely over the screaming and yelling about whether land should, or should not, be reclaimed. Clearly, disturbed areas must be reclaimed, and we must continually search for the best methods of reclamation. Our field has a collection of true and tried approaches for reclaiming lands, whether the problem involves land slides, subsidence, acid mine drainage, water management, erosion, seed bed preparation, or revegetation. But, even today new technologies and new methods are still being discovered, and we need to have open minds and to seek all the facts—not just the ones that fit our biases and past experiences—to expand our knowledge base and to implement new ideas. ■

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Letters to the Editor



Dear Editor:

In a recent edition of *Reclamation Matters*, Jeff Skousen wrote an editorial entitled "Is the Destination as Good as the Journey?" He lamented that many college students today want only the bottom line. They say, "Tell me what I have to know to pass this class—no more." I was a professor myself years ago and I heard the same thing: "Dr. Buchanan, will this material be on the exam?" Jeff mentioned, and I agree, that this is a very short-sighted attitude for young people to take just as they are beginning a lifetime journey of learning. Most professional jobs will require these students to draw from a broad-based education, but also to continually learn and update their skills. Thinking that all they need is training in a specific field is far from true. They will soon find great rewards for having a widely-based education and well-developed social and communication skills. This narrow attitude of learning only what they think is "necessary" will eventually defeat them.

Jeff's challenge was to make learning a life-long pursuit, to always be moving

forward by gathering new information and refining our thinking, and to try new things to expand our knowledge. I, too, embrace these thoughts and also believe that learning is a life-long journey, not a destination!

In 1971, I started as a 27-year-old assistant professor at New Mexico State University. During my tenure, I became well acquainted with several thousand students. Twenty years later, I left the university and formed my own consulting company. During these past 15 years, I have employed well over 100 people as laborers, technicians, scientists, consultants and two indispensable people, the janitor and the secretary. These employees have had a wide variety of expertise, experience, education and intelligence. For most new hires, it quickly becomes apparent they still have much to learn. Their training in just the sciences hasn't fully prepared them for this new "career," and they soon discover there is much more than an undergraduate education required to be successful in their new position. Over half of my employees returned to the classroom for further education, to finish an undergraduate degree or to obtain an advanced degree. With new enthusiasm, the students

now seek exposure to the many subjects considered a part of our education. They recognize the importance of getting good grades and paying attention. The narrow attitude of "give me only what I need to pass," changes to "give me all you can!"

For as early as I can remember, I was taught that every individual has at least one great talent. The great tragedy in life is for an individual to never find that talent. For those who travel through life with the "narrow attitude" Jeff spoke of, I would encourage them to change, to step up, expand their vision, and discover their talent(s). As you seek your talent and channel your love for learning, you will then discover one of man's greatest abilities—to think!

As employers, we need to encourage learning opportunities and to promote training of those who have a desire and willingness to enhance their capacities. Such programs will pay great dividends to us as employers and as a society. To employees, I say seek your talent, develop a passion for it, and forever seek to learn. Learning truly is a journey. ■

Bruce Buchanan
6 July 2006

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Reflections of a Botanist on Reclamation to Trees

Natural reclamation of drastically disturbed lands, sometimes called “moonscapes,” can be observed worldwide in all types of ecosystems (Jenny 1980). Some of the world’s most productive soils in the upper Midwest were formed after primeval bulldozing and mixing of rocks and soils by glaciers 20,000 years ago. They developed, gradually, into deep and productive soils dominated by a prairie grass ecosystem. In many ways, soil development after surface mining is similar. The lower Midwest, including southern Illinois, escaped rejuvenation by glacier dozing and has timeworn, unproductive fragipan and claypan soils, which are chiefly forested. Surface mining has produced soils with mixtures of fine-textured material and rapidly-weathering coarse fragments from lower rock layers, and these new soils have been shown to be much more productive than the native soils (Ashby et al. 1984).

My own interest in soil and vegetation relations probably began by digging soil pits in various ecosystems during and after the Second World War. I like to dig. I try to grasp the many interactions of soil and vegetation and I have been fortunate to observe many examples of ecosystem development and recovery after disturbances.

In 1946, at the University of Chicago, our field ecology class walked in the footsteps of Henry Cowles who, 50 years

earlier, had studied the bare sands constantly disturbed by wind along the shore of Lake Michigan. He and others greatly stimulated ecological understanding by documenting how beach grasses helped to form dunes on which soils with diverse forests gradually developed (Olson 1958). At Starved Rock, we saw lichen-covered sandstone outcrops contiguous with rich forests. En route, we stopped to observe a mono-culture of scattered green ash (*Fraxinus pennsylvanica*) saplings invading a landscape of “elephant hide” soil from earlier strip mining. By 1976, more vegetation had developed.

From 1950 to 1954, I worked with the USDA Forest Service in the San Gabriel Mountains of Southern California. After devastating chaparral fires, I could walk through a desolate landscape of burnt ash for 30 minutes and not see a plant. The ensuing spring brought a varied and fresh plant cover. Aerial seeding of exotic ryegrass (*Lolium spp.*) formed a temporary carpet of green, which crowded out native species and delayed recovery by natural vegetation.

High on the slopes of Mount Shasta in Northern California were mudslides with chrono-sequences of soil and vegetation made famous by Bob Crocker, whom I had known in graduate school at the University of California, Berkeley. Lower slopes were

barren from smelter fumes. Here, and at smelter-devastated Sudbury, Ontario, and Copper Basin, Tennessee, plant cover was slowly recovering naturally, and much faster where selected species adapted to the altered sites planted to aid recovery.

From 1954 to 1955, I was a Fulbright scholar with Noel Beadle at the University of Sydney, working on salinity problems in revegetating “scalds” of over-grazed sheep country in Australia. After the plant cover disappeared, water loss by evaporation and low rainfall caused salts to come to the surface. Wind-driven soil particles nipped off seedlings on the vast barren pavement-like landscape and seed supply was limited. Recovery of the “scalds” was later started by gouging furrows to trap moisture and to protect seedlings.

News media have reported miraculous and unexpected ecological recovery of moonscapes, such as after the eruption of Mount St. Helens in Washington State more than 25 years ago. I visited that moonscape a year after the eruption. As I expected, tiny signs of recovery were already widespread. The miracle would have been if the moonscape had not recovered.

In every case of drastically disturbed landscapes, the message is clear. Plant life adapts to a great diversity of environmental conditions. Some plants are “at home” in extremely harsh conditions, while others



Figure 1. Planting trees in March 1982 on ungraded spoil banks mined in 1968 in Saline Co., IL.



Figure 2. A 1981 planting (nine years old) in IL of black walnut, silver maple, bald cypress, and loblolly pine. Picture taken in August 1990.



Figure 3. Cottonwood established naturally among planted shortleaf pine on ungraded, mixed spoil, then underplanted with hardwoods. The planting was established in 1939 and this USDA Forest Service photo was taken in May 1946 (seven years old).

establish after conditions ameliorate by physical and biological processes. Drastically disturbed areas may recover slowly or rapidly, depending on the match of available plants to site conditions. Differences in inherent productivity of both soils and plants (native or introduced) affect rates of recovery.

Reclamation after Surface Mining for Coal

After 1960, I was a botanist at Southern Illinois University at Carbondale. Nearby were thousands of acres of mined lands



Figure 4. The same shortleaf pine stand from Figure 3 in April 1964 (25 years old).



Figure 5. The same shortleaf pine stand from Figure 3 at age 30 (photo taken in 1969). Most of the pine are dead or dying and underplanted hardwoods—here tuliptree—are taking over the canopy.

voluntarily planted to trees by the coal industry from the 1930s to the 1950s (Figure 1). My visits, and later research studies on these surface-mined lands, were a feast of numerous and vivid ecological lessons. Surface mining had produced prime forestland soils with mixtures of coarse fragments from rock layers lower in the overburden and of surface soil fines. These soils were well drained and deep for root growth.

Supposedly, well-understood tree species had undreamed of potentials. Handsome bald cypress (*Taxodium distichum*) were

growing on top of an otherwise barren, blackened spoil bank in western Kentucky (Figure 2). My research group, using surface mines as research parks, later found that bald cypress is very deep rooting with broad site tolerances to acidity, soil compaction, and flooding. It was greatly limited by competition in mine land plantings.

In 1947, the USDA Forest Service planted experimental tree plots throughout the Midwest on lands surface-mined for coal. A classic paper by Limstrom (1960) reported the successes and the failures on a variety of tree species after 10 years. I visited numerous plots with Steve Boyce, Bill Plass and other experienced reclamation specialists. At that time little difference was noted in performance of pines and hardwoods, with all species generally experiencing good survival and growth. Black walnut (*Juglans nigra*) and tuliptree (*Liriodendron tulipifera*) were thriving on these spoil banks (Figures 3-9). Walter Lucas had outstanding growth in company plantings of white and red oaks (*Quercus alba*, *Q. rubra*, *Q. shumardii*) (Figures 10-12), species that had been scarcely planted elsewhere. Paul Seastrom had graded pastures with fat cattle and fine apple orchards (Figure 13) on nearby lands deep-ploughed by surface mining. Lands with surface-mined soils, matched country yields for corn in Pennsylvania, and later in Illinois.

Funding for Forest Service reclamation research became limited, and I took the 15-year measurements of four local plots in 1961. In 1976, Clay Kolar and I took 30-year measurements of all remaining Forest Service plots in Illinois and Indiana (Ashby and Kolar 1977). By then, pines planted with hardwoods had largely died out (Figure 14). All remaining Forest Service reforestation plots and documented company plantings in Illinois and Indiana, were measured again in 1993 (Ashby 1996). After a half-century, differences in growth among hardwood species were evident and could be related to site conditions.

Reforestation plots in western Kentucky had been, unfortunately, re-mined before our measurement in 1976. Larson and Vimmerstedt took 30-year measurements in Ohio, and Rogers in Missouri, Kansas, and Oklahoma. About half the plant cover in many plots was natural forest invasion. Reforestation was highly successful, with scattered exceptions. Species chosen for planting, and their performance, varied



Figure 6. Black locust planting in 1938 on ungraded, mixed spoil adjacent to the shortleaf pine area in Figures 3-5 and underplanted with hardwoods. Note ground cover and volunteer hackberry, black cherry, and others. This photo was taken by the USDA Forest Service in 1978 (40 years old)

from Ohio to Kansas. New understanding of ecological amplitude was found for many tree species. Many people, evidently, had expected the supposed poor-quality soils on strip mines would not support deciduous trees. Therefore, the planting of pines had been emphasized and the oaks, especially, neglected. Oaks are important components of recent plantings.

During this period, I became acquainted with other workers in strip mine reclamation to trees. Reclamation conferences, held by Don Graves at the University of Kentucky, were supplemented by Better Reclamation with Trees conferences rotating from Kentucky to Indiana to Illinois. Later, these groups merged with Bill Plass' group from West Virginia to form the American Society for Surface Mining and Reclamation (ASSMR, now ASMR). A welcome and important part of my education was meeting Richard M. Smith at West Virginia University. He and his students/colleagues were carrying out significant soils studies that complemented my emerging understanding of soil-plant relations on disturbed sites (Smith et al. 1976). Soils and forests could be made better by surface mining.

Ivan Jansen and his colleagues at the University of Illinois, contributed greatly before his untimely death, to understanding of Midwestern soil conditions on surface mines. His work was especially important after federal strip mine law greatly changed reclamation practices. The oft-cited mantra,



Figure 7. Saplings from left to right are tuliptree, black walnut, and black locust. This picture is from Perry Co., IL with G.A. Limstrom, and was taken in 1953 by the USDA Forest Service.



Figure 8. Clay Kolar is standing amidst black walnut at age 30. Picture was taken in November 1976 in Perry Co., IL.

"What's good for corn is good for trees" has yet to be shown.

Alternative Views of Surface Mining

Most Americans do not share my views of surface mining, and textbook "environmentalists" thrive on exposing its evils. For example, Nebel and Wright (1998) cry out that "It is hard to conceive of a more ecologically destructive practice," and "Obviously this procedure results in total ecological destruction... although such areas may be reclaimed—that is, only graded and replanted—but it takes many decades before an ecosystem resembling the original can develop." Chiras (1991) lamented that "Drag-lines remove the overburden to expose the coal seam... if the land is not carefully reclaimed, it could be permanently ruined... strip mines create eyesores."

How different the real world is. An Illinois state forester designated a 40-year-old stand of white oak on an ungraded spoil bank in Saline County—with five species of native orchids in the under-story—as the best stand of white oak in the state (Figure 12). Many Forest Service reforestation plots on mined land had better tree performance than found on adjacent unmined areas.

In my view and experience, short-term landscape cosmetics have too often overruled long-term productivity as the reclamation goal! Unnoticed miracles of ecological recovery have taken place on strip mines throughout the eastern U.S. Major

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Figure 9. Roger Morgenstern stands near a tuliptree, which is 52 years old. Roots were exposed by dozer during logging operations. This picture was taken in April 1998.



Figure 10. White oak stand at age 40 in Saline Co., IL, on ungraded spoil banks. Average height at age 55 was 26 m (85 ft). This picture was taken in February 1979. Mosaics of single-species patches have given good growth.



Figure 11. In Saline Co., IL, red oak was planted in 1938 on ungraded, relatively dense spoil. Here, the trees are eight years old in this 1946 USDA Forest Service photo.



Figure 12. Rob Wikel is standing at the edge of a red oak stand planted in 1938. This picture was taken in February 1977 at age 39. Very few invading trees or ground cover is shown. This stand averaged 33 m (108 feet) tall at age 55. Red and white oak often grow naturally in separate patches or bands on a slope.

highways go through extensive tree-covered mined lands that people don't realize were previously "moonscapes." Forested mined lands are havens for wildlife and are highly valued by hunters, fishermen, bird watchers, campers, and others. Our schools need to teach honest ecology.

No one denies that some areas mined years ago with careless handling of overburden, remained eyesores for decades and contributed to serious off-site acid mine drainage (AMD) problems, especially in Appalachia. Under federal regulations, AMD is now prevented by controlled handling of sulfide-rich overburden materials (Skousen et al. 1998). Increased solubility of aluminum and other toxic ions are effects of acidity harmful to some tree species, but not to others.

River birch (*Betula nigra*) will grow on acidic soils below pH3, and pin oak (*Q. palustris*) and sweetgum (*Liquidambar styraciflua*) will grow on soils almost as acidic (Figure 15). An upland area of 659 acres in southern Illinois, tandem mined by shovel and drag-line pullback, had 28 percent ground cover (with sparse tree cover) on aerial photos in 1952, but by 1982 only 0.003 percent was still open, with earlier planted sweetgum the chief tree component. Part of the sweetgum area had been logged (Figure 16).

Extreme acidity and toxicity decrease over time as natural leaching, neutralization by basic ions, chelation by soil organic matter, biosequestration, and other changes take place under a developing forest cover. Without natural invasion or planting of adapted species such as pin oak, it may take decades before a developing forest cover ameliorates occasional toxic older sites. More commonly, such sites are limed and less acid-tolerant species are planted.

Surface Mining Regulations

Surface mine reclamation changed over the years because of unfavorable public perceptions of mining zealously promoted by "environmentalists." An original 1941 Illinois law regulating surface mining was declared unconstitutional. Later laws with increasing regulation passed judicial review starting in 1962. Placement of overburden materials, grading, and revegetation were emphasized. Tree planting greatly decreased as post-mining land use evolved into pasture and hay land uses. This approach caused extensive grading and soil

compaction to prepare a uniformly smooth seedbed for planting grasses and legumes and to provide a landscape, which tractors could maneuver. The excessive smoothing and grading, resulting in compaction of soils, reduced water-holding capacity and porosity. These soil conditions, as well as the competition from aggressive forage species, greatly reduced tree recruitment by natural invasion and succession.

These changes in post-mining land use were also a result of social and economic conditions during and following the Second World War. Labor for tree planting was scarce. Grasses and legumes were found to grow suitably on mine soils somewhat compacted by grading (Grandt and Lang 1958), and cattle prices were high. Livestock could easily move over the irregular topography with available water impoundment. Unfortunately, in forested Appalachia, isolated grasslands without cattle are commonly used in place of the more suitable post-mining land use of forestry.

Illinois laws later required extensive grading and replacement of surface soils for presumed crop production. These provisions were incorporated in the Surface Mining Control and Reclamation Act of 1977 (SMCRA), administered by Illinois and other states. In southern Illinois, reforestation has virtually been abandoned with the adoption of a "Prime Farmland Soil" regulation that led to widespread replacement of poor-quality, high-strength fragipan-type and clay soils. As a result, water penetration and tree rooting, survival, and growth became limited on these replaced prime farmland soils. Bottomland oaks, adapted to seasonal flooding and/or drought, have been most successful. Tuliptree had no survival on our plots with replaced fragipan-type soils. Again, it had vigorous growth when simultaneously planted on pre-regulation-type mixed prime forestland soils.

Illinois Highway 13—from Marion to Harrisburg—was built on land disturbed by surface mining in the 1970s, '80s and '90s. Much of the area was forested prior to mining. Now, adjacent to the highway, is a monotonous expanse of post-regulation replaced prime farmland soils. A cover of invasive grasses and old-field forbs is being invaded by autumn olive (*Eleagnus umbellata*), red cedar (*Juniperus virginiana*) and in low areas, cottonwood (*Populus deltoides*) (Figure 17). Southern Illinois is a case history of post-regulation failure to "establish



Figure 13. A young apple orchard was grown on graded spoil near Figures 2 and 3, which produced top quality apples. This picture was taken in 1976.



Figure 15. Sweetgum, planted in 1948 on spoil graded by dragline pullback, are nine years old in this picture, taken in 1957 by the USDA Forest Service. Scattered acidic soil inclusions were gradually taken over by sweetgum.

on the regraded areas, and all other lands affected, a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area” (SMCRA, Section 515(b) 19).

Behind the abandoned cropland undergoing old-field succession along Highway 13, are pre-regulation mined lands with diverse forests of maple (*Acer spp.*), hackberry (*Celtis spp.*), elm (*Ulmus spp.*), cherry (*Prunus spp.*), ash, walnut and oak. Voluntary tree planting by coal company and university reclamation specialists on pre-regulation minelands, both ungraded



Figure 17. Thousands of acres of grassland were created in the 1980s after passage of SMCRA. Many of these grasslands have been abandoned and are now being invaded by autumn olive, red cedar, and in low spots, cottonwood. Much of the area was originally forested.



Figure 14. Shortleaf pine planted in 1946 on spoil banks. This is a USDA Forest Service photo.



Figure 16. Sweetgum, at age 44, were selectively logged and thinned with larger trees used for pulp and smaller trees used for firewood. This picture was taken in July 1982.

or leveled, had successfully demonstrated the later reforestation goals of SMCRA. Knowledge and experience are now available for industry to carry out even better reclamation, if permitted to do so.

Coal is an important long-term energy resource endorsed in SMCRA by Congress. Surface mining for coal can generate new productive soils based on the full mineral resources of an overburden,

which can support forests and other land uses with greater long-term value than the coal mined. The ultimate goal of reclamation is to restore land to a productive use. Regulatory authorities in the lower Midwest have ignored these productive uses too long.

In Appalachia, the need for better implementation of SMCRA has not been ignored. Jim Burger at Virginia Tech, Don Graves at the University of Kentucky, several leading researchers at West Virginia University, and others have been active in developing and demonstrating more productive reclamation practices. A collaborative group of federal, state, industry, and university reclamation specialists, has promoted an Appalachian Regional Reforestation Initiative. Hopefully, regulatory authorities in the lower Midwest will soon recognize the value of this initiative, and the promise and goals of SMCRA can then be fulfilled.

Reclamation is too important to be the prerogative of a closed-minded, cloistered bureaucracy. Reclamation should be implemented and honored as a wide-ranging worthy profession for engineers and scientists including foresters, agronomists, ecologists, landscape architects, soil scientists, reclamation specialists, and others. Responsible implementation of SMCRA would use their talents and knowledge to realize the social, agricultural, ecological, and economic potential from deep plowing of the earth in strip mining.

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Tuesday, March 14 was a special day at the Charleston, WV headquarters of the West Virginia Coal Association. But not in a good way. The entire building was blacked out by some sort of power failure. When this happens to you at home, you can usually deal with it by leaving home (daytime) or just going to bed (nighttime).

But the office is a whole different deal. You don't realize what you're in for until you try to function. First, you can't even get into the building. It has a modern, timed locking system that operates (or doesn't) electronically. The building superintendent must be found to open the back door. Then you simply have to feel your way down a very dark hallway and fumble around with a ring of keys to open the individual business doors.

Even after that, the first thing you do when you get in the door is to flick on the light switch. Nothing. Oh yeah, you remember

the electricity is off. Habits are hard to break. There is a little window light coming through, so you make your way to the appropriate desk and then you realize there will be no computer. There is also no telephone (hey, it's not all bad news!).

Absentmindedly, you turn on the radio expecting to get the news. Sorry, the radio runs on electricity that used to come from the wall outlet. Well, maybe some coffee. Nope. You can't make new coffee and you can't even reheat yesterday's leftovers. Speaking of coffee, trips to the bathroom are just about out, because there are no windows in there. Unless you've memorized the layout, it's a risky proposition.

So there you sit, in the silent darkness, in a no-caffeine funk, with no means of communication to speak with the outside world (no consistent cell phone signal inside either), and no tools with which to do any kind of meaningful work.

All in all, a wasted day, lost in the dark!

Those who experience a day like that will come away with a new appreciation for the familiar phrase, “Coal Keeps the Lights On!” ■

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Soil Development of Reclaimed Prime Farmland over a 20-Year Period

Introduction

Public Law 95-87, or the Surface Mining Control and Reclamation Act of 1977 (SMCRA), requires that all land disturbed by surface mining be restored to the productivity it had prior to mining. As soon as the interim regulations were published, a research project was begun, in cooperation with several persons, on prime farmland being mined by Peabody Coal Company in Ohio County, Kentucky. This was on the first mine permitted in Kentucky, which had prime farmland that was to be disturbed. I think the permitting process had been started prior to SMCRA, but in any case, the experimental plots were constructed in the summer of 1978 on the Alston Mine.

Methods

Peabody Coal Company was concerned as to how they should approach the soil restoration process, since this was new to the industry in the United States. We decided to have three main treatments. The first treatment was non-prime land in which a 20-cm cover of topsoil (Ap horizon) was replaced using a scraper-pan over mine spoils or replaced overburden. These were spoils created with a drag line operation and were the base for the other two treatments, as well. These spoils were a mixture of siltstone with some thin sandstone and limestone strata. The overall lime requirement was low, with a potential acidity value of about 7 t/ac. This area was 75 m wide and 140 m in length, which allowed a 10-m buffer or turning strip on all sides of this block.

The second treatment consisted of 40 cm of subsoil (a mixture of the B2 or Bt horizons of two soils, Zanesville and Belknap) over the same spoil materials. This was also replaced with a scraper (see Photo 1). On top of this layer was placed 20 cm of the same Ap horizon. This treatment was considered non-prime cropland



Photo 1. Scraper-pan replacing subsoil.



Photo 2. Pit dug in top-soiled treatment, #1.

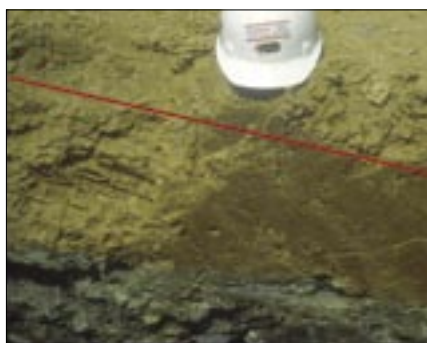


Photo 3. Pit dug in non-prime cropland treatment, #2.

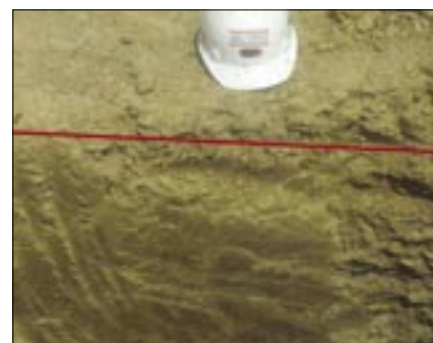


Photo 4. Pit dug in prime farmland treatment, #3.

as defined by the interim regulations. These two lifts of soil were also replaced with a scraper-pan adjacent to the first treatment. This area was the same size, with the longest side immediately adjacent to the first treatment. The turn strip overlapped between adjacent blocks and also served as a transition area between blocks with different soil depths.

The third treatment was the prime farmland area in which 80 cm of the subsoil mixture was deposited with scrapers followed with a 20-cm layer of Ap horizon. Note that this had a total thickness of 100 cm as specified by the interim regulations for prime farmland. Later, these regulations were changed to require 122 cm of total soil replacement for prime land. The overall slope of these three adjacent plots was two percent with the grade going in the direction of the prime land

treatment. This third area was the same size as the other two treatments with a 15-m buffer zone on three sides and a common buffer strip between treatments. The central portion or the prime farmland section (45 m x 120 m) was about 0.5 ha (1.3 acres) in size and was the first area restored to prime farmland conditions under SMCRA in the U.S. and worthy of a National Historical Marker.

Three pits were dug in each treatment, and it became immediately apparent that there could be a compaction problem when scraper-pans were used for soil replacement (see Photos 2, 3, and 4). Bulk density data were collected to confirm this belief. This was done by use of extracting soil cores (16 cores per treatment; see Photo 5) as well as using a bulk density gauge (one site per treatment; see Photo 6) after crops had been planted.

Soil morphological characteristics were described with the assistance of personnel from the Soil Conservation Service. Pits were dug again in 1989 after 10 years—approximately 4 m from the first set of pits—and a third set of pits was dug in 2001 after 22 years. These pits were dug in the plots where alfalfa had been planted the first five years of this experiment. The same person (Frank Cox) described the first two sets of pits, with Bill Cradock and Jerry McIntosh (now the National Resource Conservation Service) making the descriptions for the last set of pits. The various properties were analyzed statistically to determine if significant changes had occurred. These comparisons were made at the 10 percent level of significance as used by the regulations of SMCRA for other comparisons, such as yield determinations for bond release.

The initial design was to allow four cropping treatments—alfalfa, tall fescue, corn, and wheat-soybean-corn rotation—with four replications. Each plot was to have been 15 m x 15 m, so we split them in half to allow for a sub-soiling treatment. Yield measurements were taken from the various treatments for each of the crops—alfalfa, corn, wheat, soybeans, or corn—depending on the cycle in the rotation, and for the first two years from the tall fescue areas. The tall fescue areas were later used as additional turn space to allow harvesting of plots with larger equipment. Crop yields were continued from 1979 through 1983. At this point, the entire area was planted to corn for the next two years, followed with grain sorghum for two years. In the spring of 1988, a permanent cover of mixed forage was established, and yield measurements were no longer taken. Following Peabody's release of the area, the landowner harvested hay for at least three years, since all yield goals were met on this property. It is believed that the owner discontinued cutting hay due to health reasons, and later the property was sold. The University of Kentucky had an option to return to this area for additional measurements up to 2003.

Results and Discussions

Crop Yields

The target yields for all crops tested were met on all three of the soil treatments. Grain crop yield goals, however, are not required for non-prime land other than for hay. Data for alfalfa and corn are given in Figures 1 and 2, respectively. Yields were



Photo 5. Initial bulk density sampling, cores.



Photo 6. Bulk density data using a gamma density probe.

not given for 1983, as they were essentially identical to those in 1982. For alfalfa, yields increased each of the first three years. These yields exceeded the level required for Phase III bond release for the last three years. The target for the weighted average of the two soils is 6.5 t/a. Statistically, there were no significant differences between treatments any given year. Yields were significantly different between each of the first four years, but the fifth year (for which the data are not given) did not differ from the previous year.

Corn yields were good the first year, even for the non-prime or top-soiled treatment. In 1979, the growing conditions, with respect to both moisture and temperature, were ideal. The target yield for Phase III bond release for this soil is 95 bu/ac. This yield level was reached for both the non-prime and prime farmland treatments in 1982 and 1983. Again, yields for 1983 are not included, as they were essentially equal to those in 1982. Unlike alfalfa, corn yields differed significantly between several of the treatments most years. The yield difference needed to be significantly different was 8 bu/a. In addition, yields varied between years for any given treatment—except between 1982 and 1983—when they were not significantly different. The value to be significant between years was 10.5 bu/a.



Photo 7. Subsoiling sub-treatment used on the main treatments 2 and 3.

Bulk Density

The data for bulk densities are given in Tables 1, 2, and 3 (pg. 17) for samples collected initially in 1978, and after one and five years, respectively. The lower case letters denote significant differences between treatments and the upper case letters denote differences between soil depths. With the initial sampling, significant differences existed both between soil treatments and



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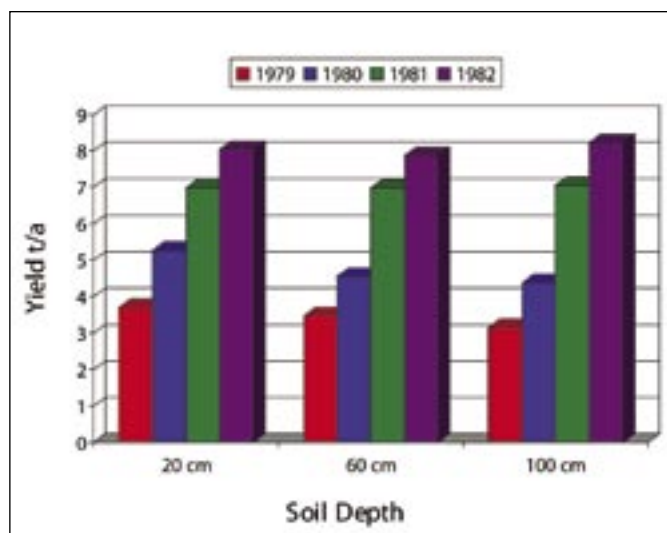


Figure 1. Effect of soil depth on alfalfa yields; the 100 cm treatment is from the prime farmland from which the soil properties are compared.

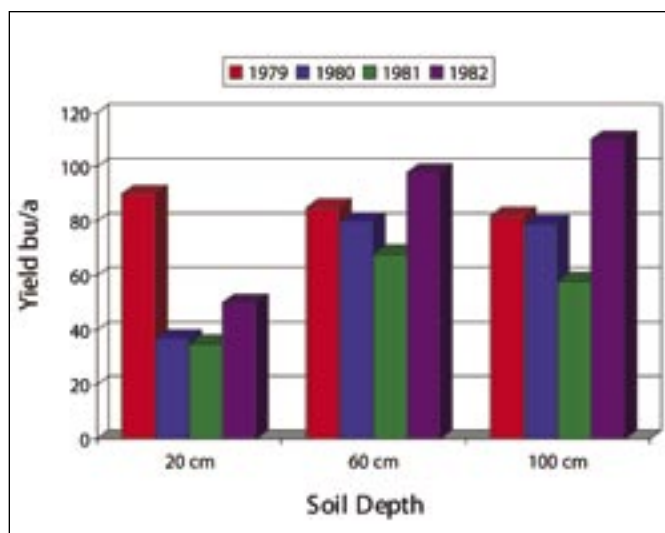


Figure 2. Effect of soil depth on corn yields; the 100 cm treatment is from the prime farmland from which the soil properties are compared.

soil depths. This was less pronounced after one and five years following soil replacement. Bulk density values were, in general, lower at the end of one year and five years, than in the initial sampling. Recall that half the area had been subsoiled, and that data from both subsoiled and non-subsoiled treatments were averaged together in Tables 2 and 3. The effect of subsoiling

was not evident after five years. In other studies (data not shown), the bulk density returned near to its pre-subsoiling bulk density in two or three years. Although subsoiling had an apparent lowering of the bulk density as shown in Tables 1 and 2—when this treatment was separated into subsoiling versus non-subsoiled in either 1979 or 1983—there were no significant differences. Had we been able to sample precisely where the subsoiling shanks had traveled, perhaps differences could have been detected, but the locations of these passes were never recorded. The equipment used to attempt to remove the higher bulk densities of the non-prime cropland and the prime farmland (treatments 2 and 3, respectively) is shown in Photo 7.

Soil structure formation was observed five years after soil replacement. In Photo 8, the development of soil horizons is indicated by the small red flags at the horizon breaks. Only a few pits were dug at that time (1983) and although profile descriptions were taken, these data are not given, since statistical comparisons cannot be made due to differences in the number of observations. This photo, as well as Photo 9, was taken from a pit dug in one of the tall fescue turn strips at the edge of a continuous corn plot. The platy aggregates are believed to have formed due to disking these plots at least four times, in preparation of the plot to plant corn. The platy aggregates were found at a depth of about 12 cm and correspond to the depth at which the disk harrow operated. Platy aggregates described in non-mined soils are not usually ascribed to a disking operation, and usually occur deeper within the soil.

Changes in Soil Morphological Properties

Soil profile descriptions were made initially, after 10 years, and then after 22 years. Data are presented in Tables 4, 5, 6, and 7 for four of the five diagnostic horizons described in 1989. These represent the Ap, BW1, BW2, and BW3. The overburden or spoils were not consistently described the various years. In 1979, these—except for the Ap—were arbitrarily assigned more or less based on depth, although there were enough differences in properties to make these assignments. A few of the horizon designations were changed when the descriptions were made in 2001 and are noted in the various tables as footnotes.

Two photos (10 and 11) are given to illustrate some of the morphological changes. Photo 10 shows some of the aggregates that had formed over the 10-year period. These were from a small area adjacent to the main plots, which had been established in alfalfa, but not planted to corn as the majority of the area, after year six. Data from this pit are not included in the summary given in the tables. This sample came from the BW1 horizon at a depth of approximately 30 cm. The second photo was taken of one of the pits dug in 2001 in the same area as those in 1979 and 1989.

The significant changes in morphological characteristics for the four horizons described, are given in green. Textures are those described in the field and occasionally are significantly different, but are not based on lab data. Soil samples were collected in 1979, and in this case the textures in the

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Table 1. Initial bulk densities, 1 month after plot construction.

Sample Depth in cm			
Trt. No.-g/cc	0-15	30-45	45-60
1	1.54a	----	----
2	1.55a B	1.71aA	1.73aA
3	1.63bC	1.67bB	1.71bA

Table 2. Bulk densities after 1 year. Average of subsoiled and non-subsoiled treatments

Sample Depth in cm			
Trt. No.-g/cc	0-15	30-45	45-60
1	1.45a	----	----
2	1.42bB	1.58aA	1.64aA
3	1.40cB	1.59bA	1.66bA

Table 3. Bulk densities after 5 years. Average of subsoiled and non-subsoiled treatments

Sample Depth in cm			
Trt. No.-g/cc	0-15	30-45	45-60
1	1.51a	----	----
2	1.55bB	1.72aA	1.68aA
3	1.56bB	1.69bA	1.72bA



Photo 8. Soil development after five years.

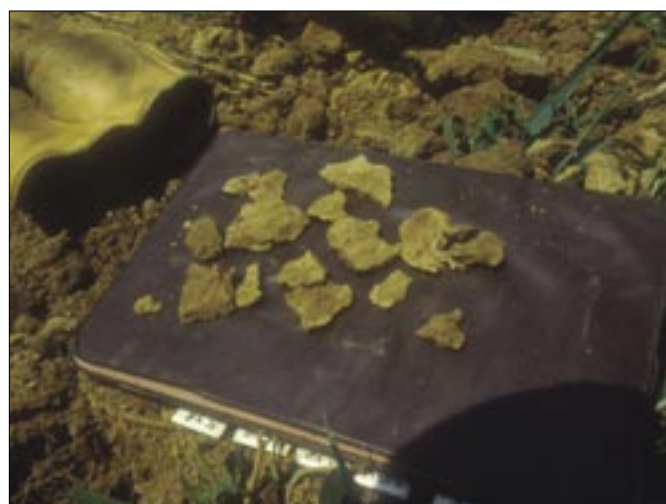


Photo 9. Close up of platy aggregates.



Photo 10. Soil aggregates 10 years after soil replacement – BW1 horizon.



Photo 11. Pit dug in prime farmland 22 years following soil replacement. Red flags mark horizon boundaries in the tables that follow.

field and lab were within the same texture class. In general the soil colors became darker when significant changes occurred. Mottles were described for the Ap horizon in the first sampling, but not in subsequent in years. Mottles in the BW horizons were observed through the 22 years. In general, the values changed and occasionally the chroma, but remained on the same page of

the Munsell color book. The abundance of roots increased for each horizon with time and a few roots were observed in the BW3 horizon for the last sampling. The soil consistency varied for the various samplings, sometimes to a more desirable condition, while other horizons became more firm.

The most significant change in morphological properties was the change

in soil structure. These changes are indicative of soil development and these changes were more rapid than some scientists may have predicted and what is commonly given in textbooks. In the two upper horizons, the development changed from weak to moderate and the size of the aggregates increased. For the BW2 horizon, the structure

Table 4. Changes in Soil Morphological Properties of the AP Horizon of Soil Treatment 3 initially seeded to Alfalfa.

Property	Initial	10 Years	22 Years
Texture	Silt Loam	Silt Loam	Silt Loam
Color	10 YR 4/4	10 YR 4/4	10 YR 4/3
Mottles	Com.Med.Dist.	None*	None
Mottle Color	10 YR 5/5	Not App.	Not App.
Structure	Wk. Fine SAS	Mod. Fine Gran	Mod. Med Gran.
Consistency	Firm	V. Friable	V. Friable
Roots	Few	Many	Many

*Items in green represent significant changes at the 10 percent level.

Table 6. Changes in Soil Morphological Properties of the BW2 Horizon of Soil Treatment 3 initially seeded to Alfalfa.

Property	Initial	10 Years	22 Years
Texture	Silty Clay Loam	Silt Loam*	Silt Loam
Color	10 YR 5/5	10 YR 5/4	10 YR 4/4
Mottles	Com.Med.Dist.	Com.Med.Dist.	Com.Med.Dist.
Mottle Color	10 YR 6/5	10 YR 6/2	10 YR 5/3
Structure	Massive	Wk. Med SAB	Mod. Coarse SAB†
Consistency	Firm	V. Firm	Firm
Roots	None	Few	Common fine

*Significant Changes at 10 percent level

† Weak Med Prismatic breaking to SAB

Table 5. Changes in Soil Morphological Properties of the BW1 Horizon of Soil Treatment 3 initially seeded to Alfalfa.

Property	Initial	10 Years	22 Years
Texture	Silty Clay Loam	Silt Loam*	Silt Loam
Color	10 YR 5/5	10 YR 5/4	10 YR 4/3
Mottles	Com.Med.Dist.	Com.Med.Dist.	Com.Fine Faint
Mottle Color	10 YR 5/5	10 YR 5/2	10 YR 5/3
Structure	Wk. Fine SAS	Mod. Med SAB	Mod. Med SAB
Consistency	Firm	Friable	Friable
Roots	None	Common	Common fine

*Items in green represent significant changes at the 10 percent level.

Table 7. Changes in Soil Morphological Properties of the BW3 Horizon of Soil Treatment 3 initially seeded to Alfalfa.

Property	Initial	10 Years	22 Years
Texture	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam
Color	10 YR 5/5	10 YR 5/4*	10 YR 4/4
Mottles	Com.Fine.Dist.	Few Fine Faint	Com.Med.Dist.
Mottle Color	10 YR 6/4	10 YR 4/3	10 YR 5/6
Structure	Massive	Wk.Med SAB	Massive, Relict Brit.
Consistency	Firm	V. Firm	V. Firm
Roots	None	None	V. Few fine

*Significant Changes at 10 percent level

†Described as a "C" horizon 2001

changed from massive to weak to moderate sub-angular blocky, whereas the BW3 changed from massive, to weak sub-angular blocky. For the last sampling of this horizon, the structure was described as massive, but was believed to be a relic brittle condition of the originally replaced soil. This could also indicate that the fragile conditions described in the Zanesville silt loam soil were returning. Additional sampling sometime in the future

would be required to verify that this was occurring. Note that the platy structures were not observed for the 10- or 22-year sampling, and it is speculated to have disappeared, as the disk harrow was not used after the fourth year.

Summary

Restoration of prime farmland, the first area reclaimed in Kentucky if not the U.S., was successful. The yields of all crops tested (alfalfa, corn, grain sorghum, soybeans, tall fescue, and wheat) met yield requirements for Phase III bond release, as specified by the regulations associated with SMCRA. The soil morphological characteristics changed significantly over the 22-year period that profile descriptions were taken.

Acknowledgements

I wish to acknowledge the assistance of several persons over the years this project existed: Jim Powell, Brent Gray, and Joey Armstrong – all former employees of Peabody Coal Co.; Frank Cox, Bill Cradock, and Jerry McIntosh of NRCS; and students Lynn Ellis and Rachel (Creamers) Kingery. Grants from the Peabody Coal Co., Office of Surface Mining, and the Kentucky Reclamation Association, as well as the College of Agriculture, University of Kentucky, allowed this project to be completed. ■



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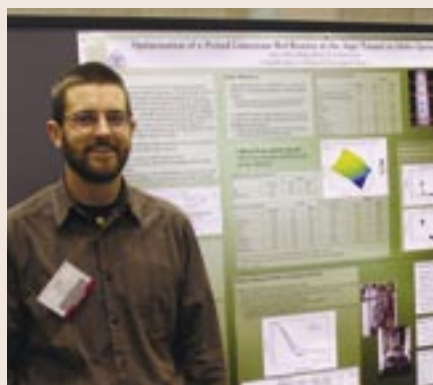


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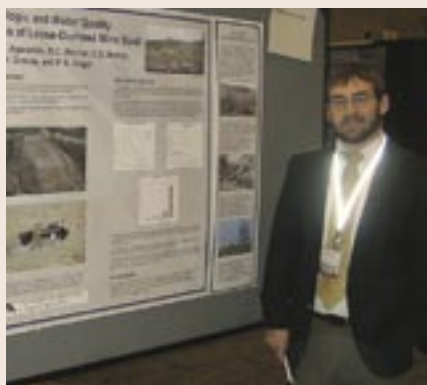


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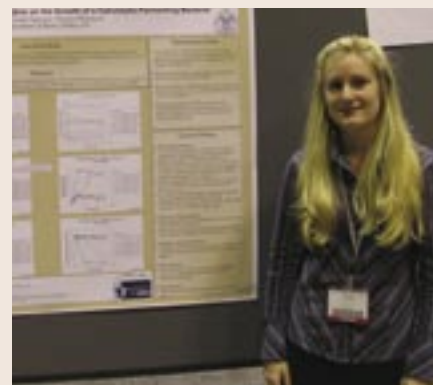
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The Questa Rock Pile Weathering Project: A Rare Opportunity for NMT Students

Introduction

The Questa Rock Pile Weathering Study has been the source of many opportunities for dozens of students at the New Mexico Institute of Mining and Technology (New Mexico Tech) over the last two years. The project is aimed at studying the effects of weathering on the physical stability of mine rock piles at the Questa Mine in northern New Mexico, USA. It is being undertaken by university researchers and consultants and funded by MolyCorp Inc., the owner and operator of the mine. The research-oriented nature of the project and the diverse and unusually large amount of field, laboratory and computer work involved has made the use of students from various universities indispensable. At the same time, students who have the opportunity to work on the project gain rare experiences and skills that are required in the job market today. This article describes how New Mexico Tech students are being involved in the project, the training and experience that the students are getting and how they and their future employers stand to gain from these opportunities.

Students with Assorted Backgrounds

New Mexico Tech (NMT) in Socorro, New Mexico, is one of several universities working on the Questa project. Dr Virginia McLemore (Sr. Economic Geologist) of the New Mexico Bureau of Geology and

Mineral Resources, a division of NMT, is the principal investigator in charge of all the field work and most laboratory and data handling work for the project team. She engages NMT students as hourly workers and research assistants to meet the staffing needs of the project. Some of the students have the opportunity of doing their theses and dissertations on the project. So far, 35 students with diverse backgrounds in terms of level of study, field of study and nationality, have been employed on the project. They include 20 Americans, 9 Brazilians, 3 Ghanaians, an Indian, an Iranian and a Nigerian. Seven of the Brazilians were exchange students who studied for only one

semester each at New Mexico Tech. Table 1 shows the distribution of the students among majors and levels of study. One of the Masters students in Geochemistry has already completed her Directed Research on the project. Six other Masters students (2 from hydrology and 4 from Mineral Engineering) are writing their thesis on the project, and the PhD student from Chemistry is using the project for part of his dissertation. In addition, students from the University of British Columbia (UBC), University of Saskatchewan, and University of California, Berkeley have been involved with the project and worked with the NMT students.

Table 1: Fields and Levels of Study of Student Workers

Major	Level of Study			Totals
	Bachelors	Masters	PhD	
Biology	2	-	-	2
Chemistry	3	-	1	4
Chemical Engineering	2	-	-	2
Electrical Engineering	1	-	-	1
Geochemistry	-	2	-	2
Geology	2	2	-	4
Geophysics	-	1	-	1
Hydrology	1	2	-	3
Mechanical Engineering	1	-	-	1
Mineral Engineering	9	6	-	15
Totals	21	13	1	35

Safety Training

Perhaps, the first and foremost asset that students, especially those who are involved in field work, gain from this project is the safety training programs that are required for one to work on most aspects of the project. The students take the National Safety Council Defensive Driving course before they are permitted to use NMT vehicles, which are the vehicles the team uses for field work. All field workers on the project go through the Mine Safety and Health Administration (MSHA) Part 48 training and on-site safety training at the mine prior to working on the site. The on-site training is usually handled by the Safety Specialist of the mine and covers topics including:

- Hazard recognition and resolution
- Use of personal protective equipment (PPE)
- Incident reporting
- Use of two-way radio communication systems
- Safety in performing routine field work such as driving, lifting, cutting, digging and climbing under different weather and ground conditions
- Inspection of vehicles and other field equipment
- Prevention of health hazards such as hanta virus, hypothermia and altitude sickness
- Appropriate clothing for field conditions and
- Managing encounters with wildlife such as bears, deer and mountain lions.

The team is required to have a safety meeting every morning before going to the field to work. At these meetings the students are given the opportunity to present short safety talks and to point out other safety concerns they might have.



Fig. 1: Sampling and measurements in a trench. Three benches are shown in the photo.

Field Operations

All the tasks carried out in the project may be grouped into field, laboratory and administrative or office functions. Field work includes sampling and instrumentation. Students are involved in sample collection from rock pile surfaces, trenches in the rock piles, open pit walls and alteration scar areas. Samples were collected from trenches that were dug in the Goathill North rock pile during the mitigation construction of the pile from Fall 2004 to Spring of 2005 (Fig. 1). Students were trained in working safely in and around trenches. Splits of drill core and drill cuttings obtained from previous investigations at the mine by other organizations were sampled using a rock core splitter and a soil splitter respectively (Fig. 2). Water samples were also collected from precipitation collectors installed at various locations on the rock piles. For the students to be able to handle the samples properly, they are trained in sampling protocols including the use of chain of custody forms to track samples.

In addition, students help with field measurements and installation of instruments. Precipitation collectors (Fig. 3) and tensiometers (Figs. 4 and 5) were installed to take measurements over long periods of time. Instruments that are used for routine field measurements include:

- Tension infiltrometer (Fig. 6)
- Guelph permeameter (Fig. 7)
- Gas analyzer
- Soil temperature probes (Fig. 8)
- Thermal camera (Fig. 9)
- Soil pH and saturation probe (Fig. 8)
- Geographical Positioning Systems (GPS)
- Air temperature, humidity and wind speed instrument
- Brunton compass



Fig. 2: Splitting drill cuttings with a soil splitter



Fig. 3: Installation of a precipitation collector



Fig. 4: Digging to install a tensiometer. One is already installed at the back.



Fig. 5: Connecting tensiometers to a data logger powered by solar cells

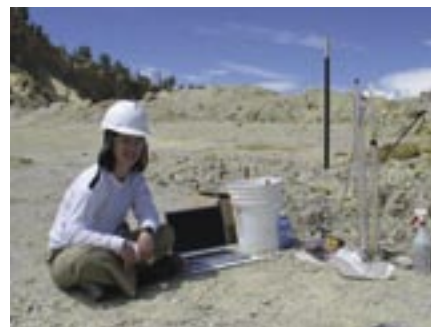


Fig. 6: Measuring hydraulic conductivity with the tension infiltrometer



Fig. 7: Preparing to measure hydraulic conductivity with the Guelph Permeameter



Fig. 9: Measuring the temperature of rock pile surface with a thermal camera at about 2 a.m.



Fig. 11: Performing particle size analysis



Fig. 8: Measuring soil temperature, pH and degree of saturation



Fig. 10: Shear box test



Fig. 12: Hydrometer test

Laboratory Work

The project uses laboratories at New Mexico Tech for preparing samples and performing various geotechnical and geochemical tests on them. Most of the lab work is done by students, some of whom are trained and supervised by other students. Sample preparation procedures include drying, crushing, pulverizing and preparation of pressed pellets and thin sections from rock and soil samples as well as microwave digestions and separation of precipitation samples from mineral oil. Some of the geotechnical tests include shear strength (Fig. 10), Atterberg limits, point load, slake durability, particle size (Fig. 11) and hydrometer (Fig. 12) tests. Geochemical tests that are done by students include paste pH, paste conductivity, paste total dissolved solids (TDS), paste oxidation-reduction potential (REDOX), acid-base accounting (ABA) (Fig. 13), net acid generation (NAG), fluoride analysis (Fig. 14), and elemental analysis using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and Inductively Coupled Plasma Mass Spectrometer (ICP-MS) on soil samples. Also, pH, conductivity, alkalinity and elemental analysis are done on water samples. Although these tests are not new, some of the procedures

were modified and written up by students to fit the specific facilities available and the needs of project.

Administrative Work

A large amount of computer and other office work is involved in this project and students do a lot of it. All the data generated from field and lab work are managed in a Microsoft Access database. Students enter sample data into the database soon after the samples are collected from the field and they add test results to the database as they are generated. Additionally, students analyze data from the various tests and prepare reports and presentations on them. Some of the students are directly in charge of purchasing equipment and supplies for the labs and field work. The students also perform other duties such as literature searches and bibliographies, and writing of standard operation procedures (SOPs) for field and lab procedures.

Advantages to Students and Future Employers

The various duties assigned to the students give them the opportunities to learn many different skills, most of which are not taught in the classroom. These skills include hazard awareness training

and evaluation of potential health and safety issues when working on a project. Most of the students have gained hands-on experience with instruments and test procedures that would otherwise remain unknown to them. This exposure has increased their aptitude to learn more practical skills in the future. A lot of the work is done in groups and sometimes students lead groups to do field, lab or office work. This helps the students to appreciate the value of team-work and to establish good working relationships with people with different backgrounds.

Most of the students have improved their communication and administrative skills. The amount of report writing and oral presentations that students are asked to do and the various audiences to which they present gives them the opportunity to learn better presentation and scientific writing skills. In addition to all these, Dr. McLemore has assigned a trained editor on the project the duty of teaching some of the students to write more proficiently in English. Some of the students who come from non-English-speaking countries such as Brazil find this opportunity even more useful because it also helps them with their academic work in general. Moreover, the graduate students

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Fig. 13: Acid Base Accounting test



Fig. 14: Fluoride analysis

often get the chance to present the results of their work to the entire project team of over 20 people and at conferences of organizations such as the New Mexico Mining Association (NMMA), Society for Mining, Metallurgy and Exploration Inc. (SME), New Mexico Geological Society (NMGS), Geological Society of America (GSA), and American Society of Mining and Reclamation (ASMR).

In summary, the Molycorp project is a great opportunity for students who are involved in it because they are equipped with very good employable skills to better prepare them for future employment in both academia and industry, and for further studies. Organizations that employ any of these students will find in them priceless qualities such as good leadership, organizational and communication skills, an aptitude for teamwork, hazard-recognition and good general work ethics—qualities that are not always easy to come by in fresh graduates from college or even graduate school. ■



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