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ABANDONED MINE LAND RECLAMANTION SITES IN SOUTHERN ILLINOIS

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INTRODUCTION

The field trip will visit three abandoned coal mine sites in Jackson and Williamson Counties in southern Illinois. The sites were chosen to illustrate environmental damages caused by past coal mining. Specifically, we will be looking at the causes and effects of acid mine drainage (AMD) at these sites.

GENERAL GEOLOGIC SETTING

The sites are all located at the southern edge of the Mt. Vernon Hill Country of the Till Plains Section of the Central Lowlands Physiographic Province (Fig. 1). This area is a low relief, dissected bedrock surface cut in Pennsylvanian age sedimentary rocks. A thin glacial cover is present but has little physiographic expression. The field trip area lies near the southeastern boundary of the Illinois Basin, a nearly 50,000 sq. mi. structural basin in Illinois and adjacent parts of Indiana and Kentucky, which evolved through much of the Paleozoic Era. During this time, the basin was trough-like and open to the south (seaward). Up to 15,000 feet of Cambrian through Pennsylvanian age sediments (Fig. 2) accumulated in this trough. The present spoon-shaped geometry of the basin was created sometime during the Mesozoic Era with the rise of the Pascola Arch to the south. Rocks of Permian to Cretaceous age, if they existed in the field trip area, have since been eroded away.

Sediments filling the basin were primarily marine carbonates through Mississippian time. These gave way to an influx of terriginous sediments during the Pennsylvanian Period in the form of repeating sequences of non-marine to marine sediments ------ the classic "cyclothems" of Wanless and Weller (1932). There are 54 named cyclothems in the Illinois Basin Pennsylvanian sequence, containing 52 named and about 25 unnamed coal beds. The entire Pennsylvanian sequence, originally called the "coal measures", thickens toward the center of the basin near the Illinois-Indiana border in southern Illinois where it reaches a thickness of about 2500 feet. Within the field trip area to the southwest, the sequence is between 700 feet (stop #1) and 1000 feet (stops #2 & #3) thick, with individual strata dipping gently to the northeast toward the center of the basin.

The dominant coal units in southern Illinois, in terms of production, are the Springfield-Harrisburg (#5) and the Herrin (#6) coals within the Carbondale Formation. These two units have accounted for more than 80% of mined coals in the region. Their outcrop edge lies a few miles north and east of the city of Carbondale and about 7 miles northeast of Stop #1. Coals mined within the field trip area are lower in the

Pennsylvanian sequence within the Spoon Formation (Fig. 3). They tend to be areally limited and discontinuous.

Pennsylvanian and older rocks in the field trip area are bounded by three major fault systems: the Rough Creek Graben and Reelfoot Rift systems to the north and east, and the Cottage Grove Fault system to the north. The former are primarily normal faults with up to 1000 feet of vertical displacement. Motion on the Cottage Grove system is mostly strike-slip. These deep-seated fault systems appear to have been active through much of the Paleozoic Era. Subsidiary faults associated with these systems are frequently encountered in local underground coal mines where they can cause mine flooding and roof stability problems.

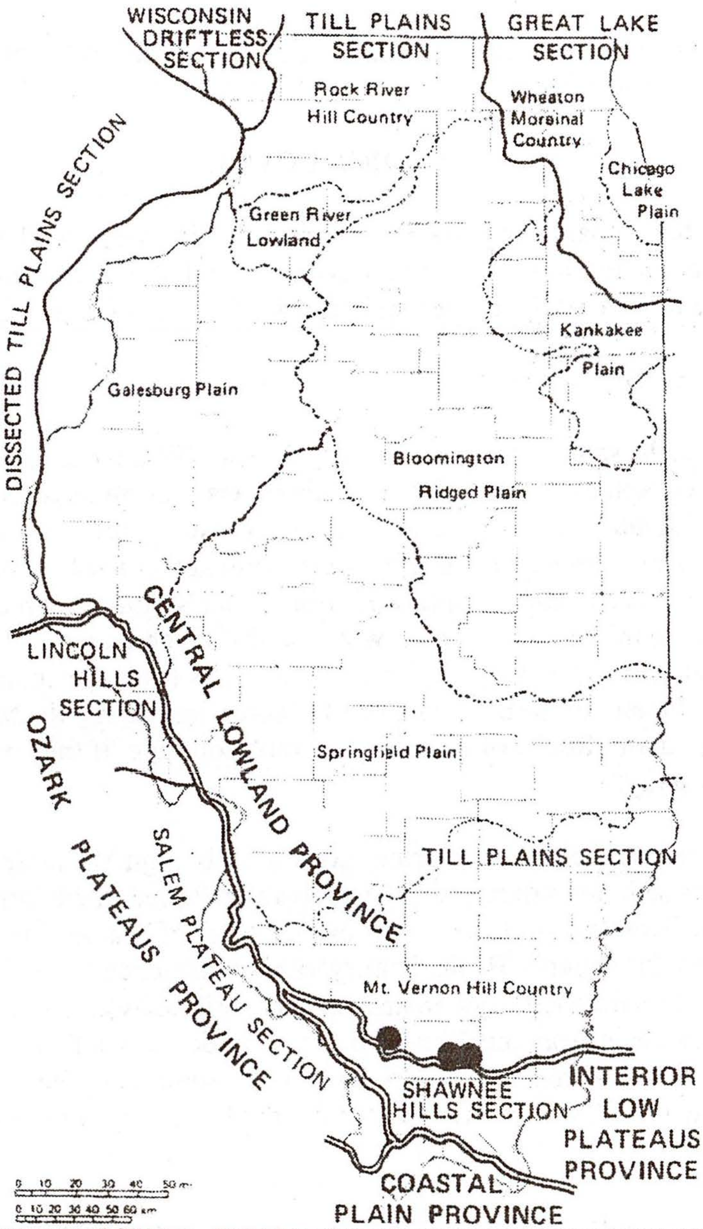

Figure 1 – Physiographic divisions of Illinois. Field trip sites shown as black dots (adapted from Illinois State Geological Survey, 1995.

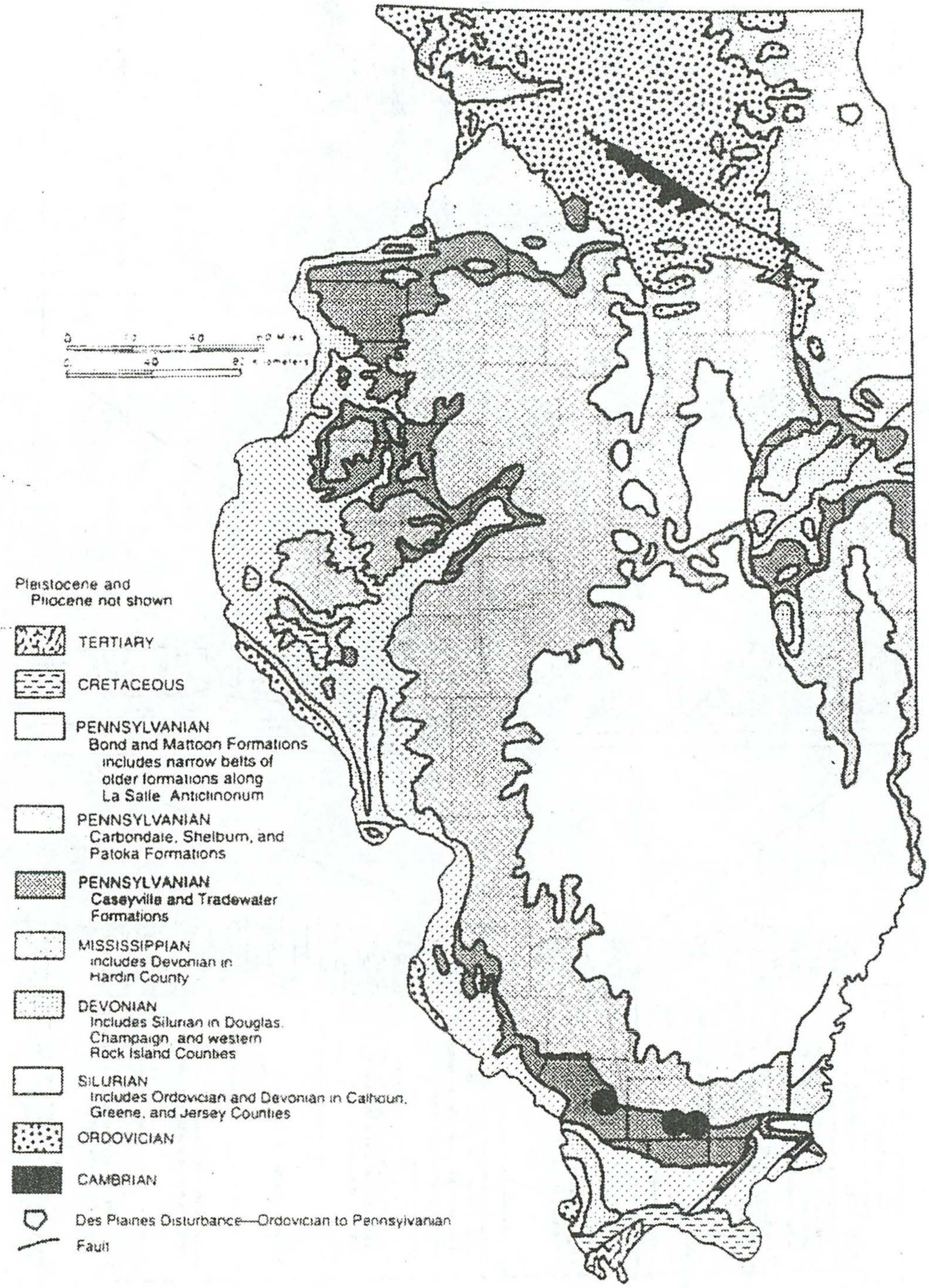

Figure 2 – Bedrock geology of Illinois. Field trip sites shown as black dots (adapted from Illinois State Geological Survey, 1995)

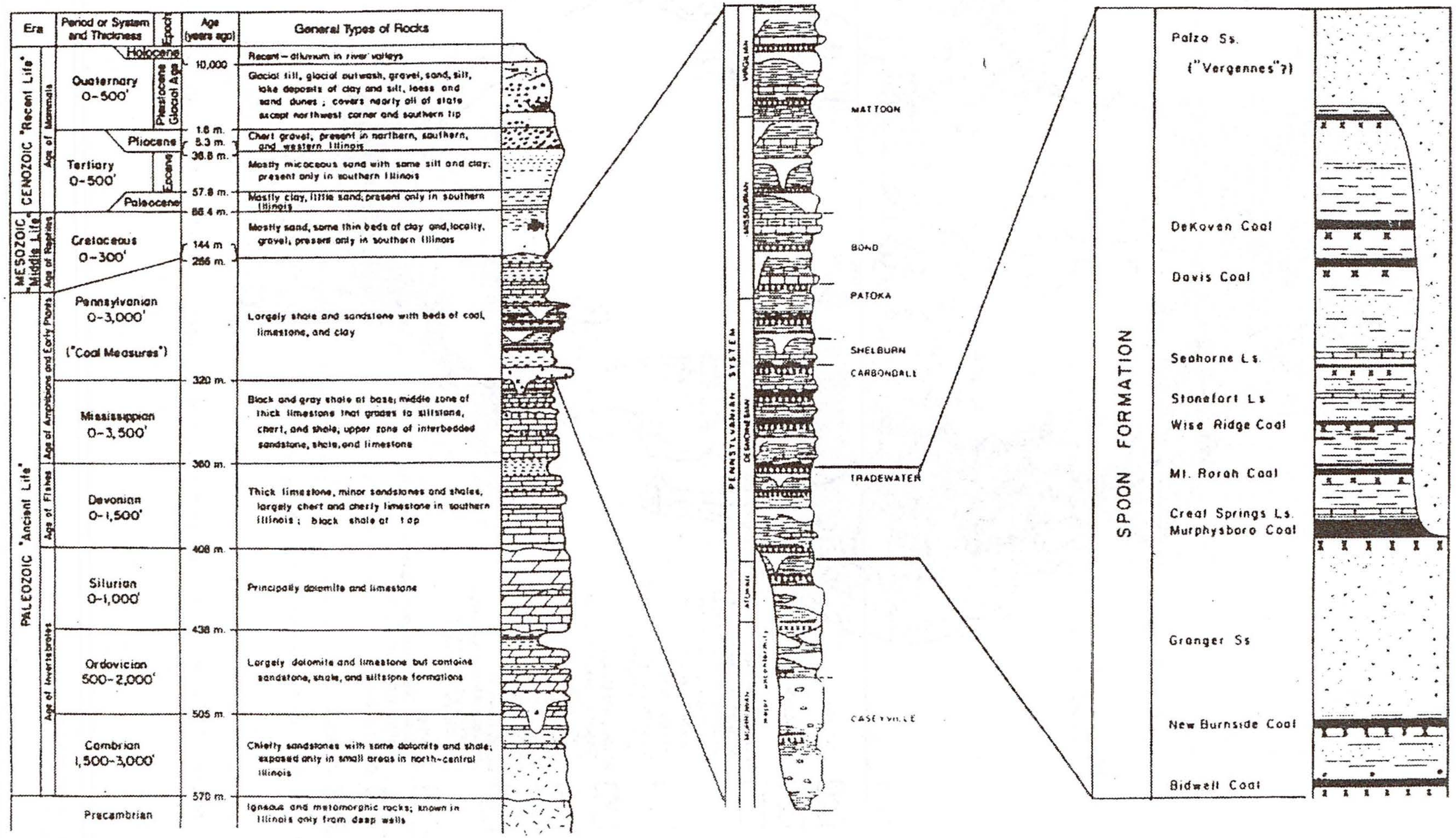

Figure 3 – Stratigraphic relationships in southern Illinois (modified from Illinois State Geological Survey, 1979, 1995).

The effects of glaciation are not strongly expressed in the field trip area. Ice from the Illinoisan glaciation (300,000? - 125,000 BP) reached its southernmost limit about 15 miles south of the area. Till deposits of Illinoisan age are thin and patchy on uplands. Much of the upland contains a thin veneer of Peoria Loess deposited following the last (Wisconsinan) glaciation. Valleys between uplands are partially filled with lacustrine silts and clays of the Equality Formation. These deposits were laid down in slackwater lakes created in tributaries when, during deglaciation, rapid aggradation of the Mississippi and Ohio Rivers created temporary dams at the mouths of the tributaries.

COAL MINING IN SOUTHERN ILLINOIS

Coal mining in southern Illinois began in the early 1800's, but did not become economically important until the 1860's when, during and after the Civil War, rapid expansion of the nation's railroad system took place. Until the 1930's coal was mined exclusively by underground methods, in which some of the coal was left in place as roof-supporting pillars. This "room and pillar" method typically extracted 50% to 70% of the coal. The mined coal was processed on-site and the waste material, sand to gravel size pieces of coal and shale called "gob", was dumped into large piles. We will see the remnants of one of these gob piles at Stop #1.

By the early 1900's, several hundred underground mines were operating in southern Illinois. They ranged from small "mom and pop" operations for local consumption to the large shipping mines supplying coal to the major railroads and to cities such as St. Louis and Chicago. Today, only two underground mines are operating in southern Illinois.

The scale of coal mining changed dramatically in the late 1920's with the advent of surface (strip) mining. By the 1970's this mining method accounted for almost half of annual production in southern Illinois. Roughly 22,000 acres in Jackson and Williamson Counties have been affected by strip mining operations. In surface mining the overburden above the coal seam, which may be up to 150 feet thick, is removed by shovel or dragline and deposited in an elongate "spoil" ridge opposite the working face. As mining advances, successive parallel to subparallel spoil ridges are built. The working face, or highwall, can be almost vertical. The elongate trench between the highwall and the youngest spoil ridge is called a final cut. When mining operations cease, this trench usually fills with water to form a final cut lake. These long, narrow lakes are ubiquitous in the field trip area and southern Illinois in general.

Strip mining causes significantly more environmental degradation than underground mining, since it involves large scale surface disturbance. Barren or sparsely vegetated spoil ridges, besides being considered eyesores, take the land out of productive use and are prone to severe erosion. Highwalls and final cut lakes are often a danger to the public. More importantly, the mine spoil in the ridges contains clay to boulder size pieces of the overburden, mainly shale, which may be highly pyritic. It is the oxidation of pyrite in mine spoil and gob which causes acid mine drainage and the resultant contamination of nearby lakes, streams and rivers. The relatively high pyritic sulfur content of Illinois coals has been a major contributor to the decline of the coal industry in the State.

ABANDONED MINE RECLAMATION

In 1977, Congress enacted the Surface Mining Control and Reclamation Act (SMCRA). This law, among other things, provided federal funding for reclamation of lands adversely impacted by coal mines abandoned prior to 1977. The funds come from a per-ton surtax on active coal companies. These funds are returned to the states on a needs basis. In Illinois, reclamation under the program is performed by the Abandoned Mined Lands Reclamation Division, a part of the Illinois Department of Natural Resources. Since 1979 the AMLRD has reclaimed more than 9000 acres in the State at a cost of more than $140,000,000. Most of these reclamation efforts involve regrading spoil ridges to establish positive drainage and decrease infiltration, eliminating dangerous highwalls and mine openings, and establishing a vegetative cover. The three stops on this field trip illustrate different aspects of the reclamation process.

Stop #1 - Tab/Simco Site

This site (Fig. 4) is a horseshoe-shaped upland 120 feet above the surrounding lowland, and consists of about 30 acres of underground mine works in two coal seams, which dip gently to the north-northeast (Fig. 5). The lower seam (Murphysboro Coal), is a continuous, 7 foot thick unit which was mined-out using the room and pillar method under the entire "horseshoe". The upper seam (Mt. Rorah Coal) is a thin, 0 - 3.5 foot thick, discontinuous unit that was mined only in the southern part of the site. The two coals are separated by 15 to 35 feet of shale (unnamed), and are probably connected by one or more vertical shafts (Fig. 6) Beneath a thin loess cover, the upland is capped by a 15 - 30 foot thick channel sandstone (Vergennes?) which locally cuts out units down to the lower shale. This sandstone is fine grained, micaceous and well-jointed, with occasional subvertical fracture zones. It can be seen at two locations on the path leading to the north end of the site.

Underground mining began here in 1890, or earlier, and ceased in 1955. An estimated 45 acres were mined. Strip mining of both coal seams along the south, east and north fringes of the "horseshoe" began in the early 1960's and ceased in 1975. The stripping operation removed an estimated 15 acres of the older underground works, resulting in numerous "break-ins" into the older works. Some of these "break-ins" are responsible for the severe AMD problem at the north end of the site. In 1998, the AMLRD eliminated the south highwall and final cut pit by regrading the adjacent spoil ridge up to almost the top of the highwall.

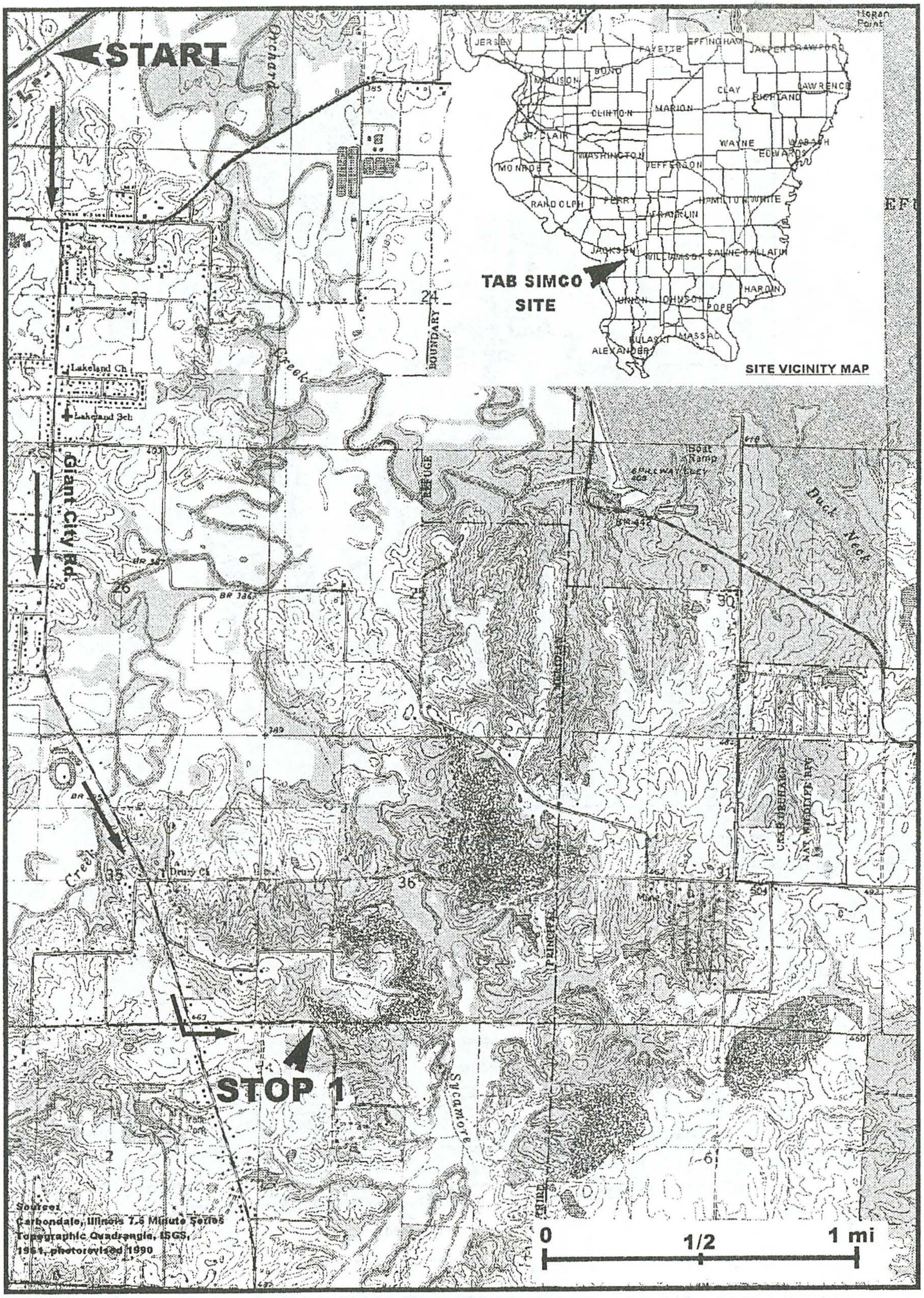

FIGURE 4 - Tab/Simco Site

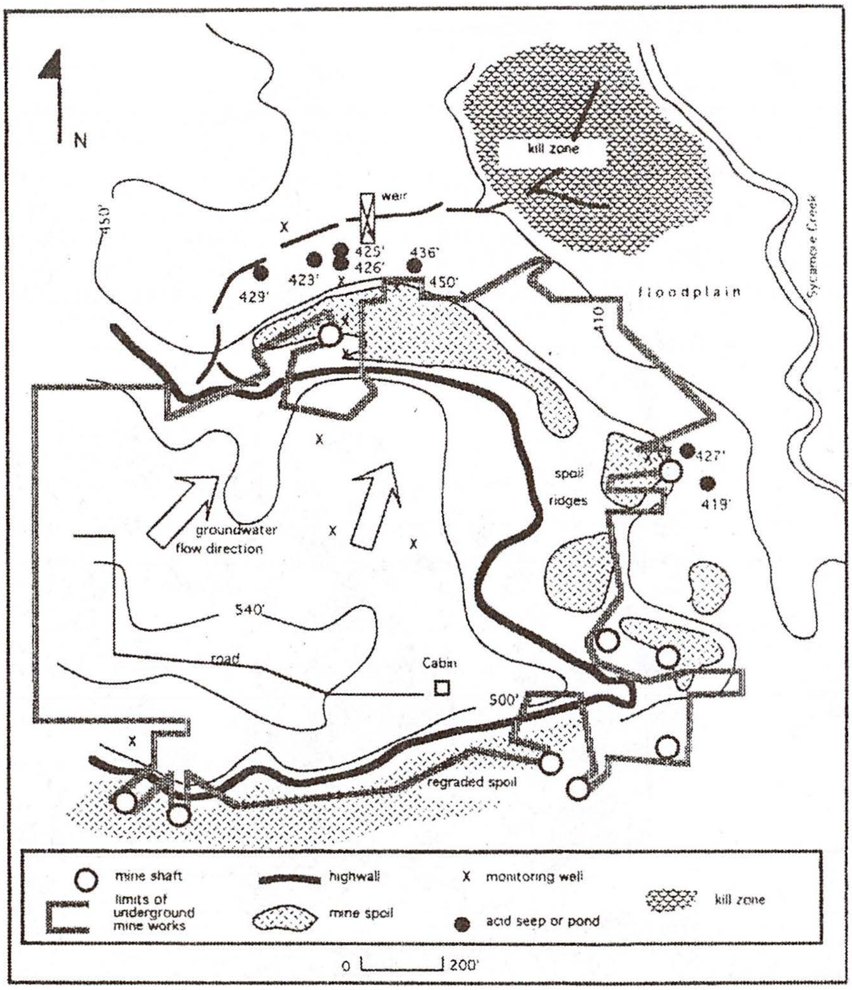

Figure 5 – Plan view of the Tab/Simco site.

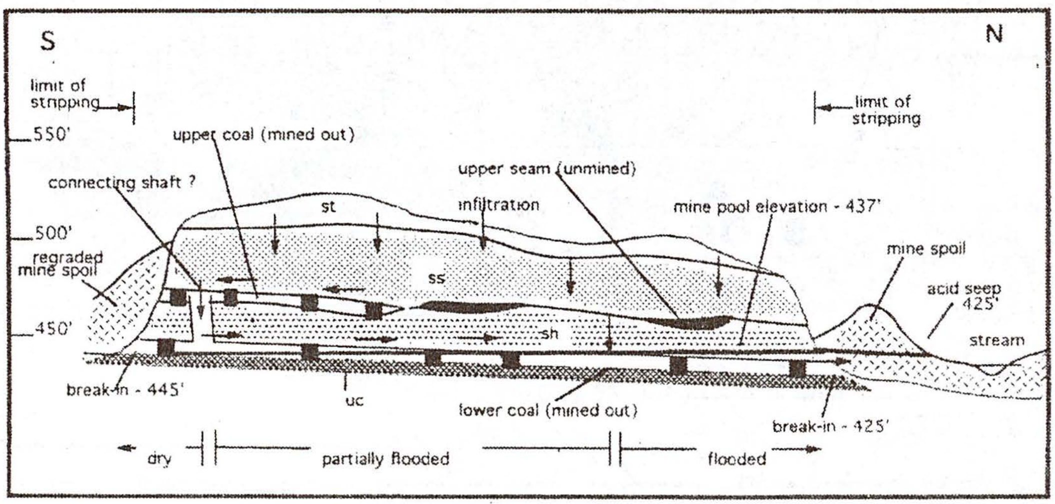

Figure 6 – Schematic N – S cross section of the Tab/Simco site showing stratigraphic relationships, upper and lower mine works, inferred infiltration pathways, and mine pool elevations in the lower (Murphysboro) coal seam.

The severe environmental degradation caused by AMD is well expressed along the northern edge of the "horseshoe". Here, AMD with a pH range of 2.2 - 2.9 exits the remnant of a gob pile as four distinct seeps. Note the high coal content of the sediment in this area. A small acid pond with pH ~ 2.5 is also present about 250 feet west of the seeps. The origin of this pond is unclear. Acid discharge from the seeps and pond enters a small tributary which flows east and north into an approximately 10 acre "kill zone" (Fig. 7), and then into Sycamore Creek. This creek is degraded by AMD for several miles downstream. Aquatic life no longer exists in this stretch of the creek. The "kill zone" is also severely contaminated with AMD and has been expanding continuously since mining operations ceased in 1975. It consists of about 1 foot of highly acidic, resedimented gob deposited by the tributary in a manner similar to a prograding delta.

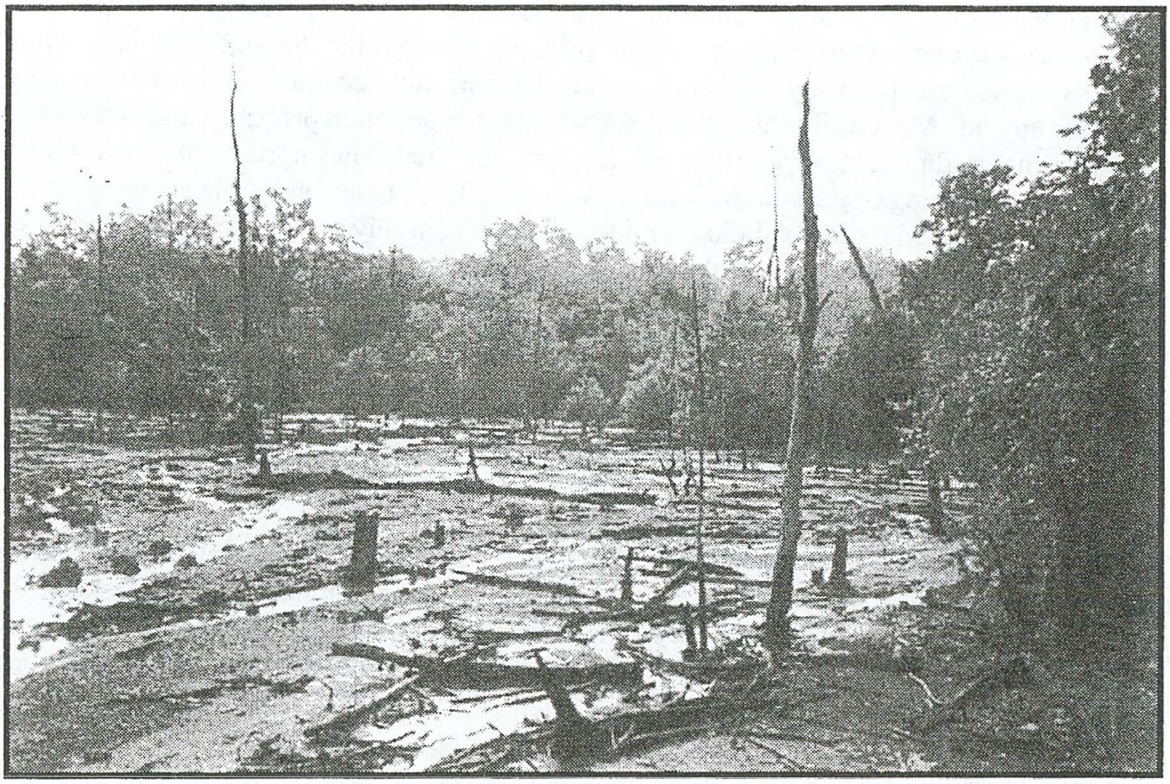

FIGURE 7 - The "Kill Zone" at the Tab/Simco site. Looking North.

AMD is generated both within the old mine works and in the adjacent spoil/gob by percolating infiltration water in contact with the oxidation products of pyrite (FeS_2). These products are ferrous iron (Fe^{+2}), sulfate (SO_4^-), and hydrogen ion (H^+). In an oxidizing environment the ferrous iron oxidizes to ferric (Fe^{+3}), with the release of more H^+ acidity. This process is greatly accelerated by the action of iron-oxidizing bacteria such as *thiobacillus ferrooxidans*. Upon further oxidation and hydrolysis, such as is occurring around the seeps, the iron precipitates as a reddish to yellowish hydrous oxide (FeO(OH)) called "yellow boy". Yellow boy is a form of the mineral limonite. It has precipitated as pore fillings in the sediment, and as a thin surface crust at and downslope from the seeps. It can also be seen along the acid tributary and throughout the "kill zone". Limestone rip-rap lining the tributary channel at an installed weir has been armored and cemented by this precipitate, thus destroying its neutralizing potential. As can be seen, the seep area serves as a hospitable environment for acidophilic (acid-loving) green algae. A representative chemical composition for the AMD at any of the seeps would be:

Acidity	2200 mg/L
Alkalinity	0 mg/L
Total Iron	700 mg/L
Aluminum	250 mg/L
Magnesium	175 mg/L
Sulfate	950 mg/L
pH	2.5

The driving force for the acid seeps is a highly acidic (pH= 2.3 - 3.0) mine pool in the underground mine works which fluctuates seasonally in volume (Fig. 6). The pool is derived from infiltration through the jointed sandstone, and probably from surface runoff into abandoned boreholes, mine shafts, and subsidence pits on the upland. Most infiltration into the worked out upper seam probably finds its way via connecting shafts into the up-dip (south) end of the lower seam, and then flows northward to several break-in points created by the stripping operation. As water flows along the floor and sides of the old underground works, it dissolves accumulated pyrite oxidation products, including highly soluble acid sulfate salts such as jarosite ($KFe_3(SO_4)_2(OH)_6$) and rozenite ($FeSO_4.4H_2O$), and eventually flushes them out through the break-ins. These salts represent "stored" acidity since their dissolution adds H^+ ions to the mine pool and further decreases pH. For this reason, the mine pool has a lower pH during high water periods than low water periods. Still more acidity is picked up as the water flows through the gob and exits at the seeps. It is estimated that the mine pool contains between 12,000,000 and 22,000,000 gallons of acid water, depending on season. Its discharge rate to the seeps is a relatively consistent 36,000 gpd, even during dry periods. This translates into a residence time for the mine pool water at between 0.9 and 1.7 years.

Reclamation of the northern end of the "horseshoe" is slated for the near future. The method(s) of reclamation have not yet been determined, but could involve a combination of AMD abatement techniques, such as in-mine injection of alkaline material, isolation and sealing of the break-ins, and passive wetlands systems. However, reclamation options become increasingly limited as new, expensive homes continue to be built on the upland.

Lunch Stop – Giant City State Park

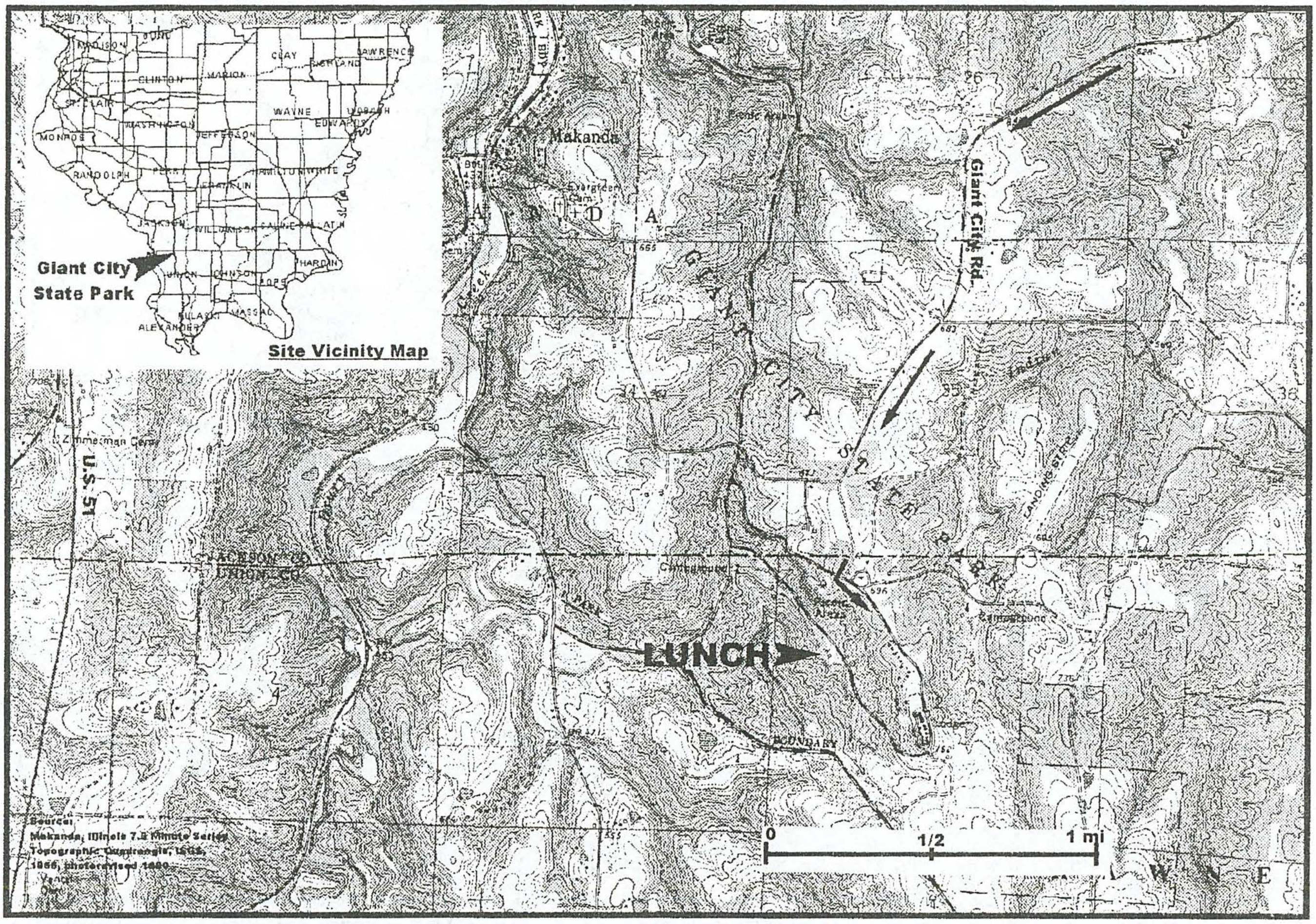

FIGURE 8 - Giant City State Park (lunch stop)

Stop #2 - Palzo Site

At this site (Fig. 9) we will briefly investigate some AMD deposits and the effects of AMD on a nearby stream. The Palzo site in southeastern Williamson County is a 312 acre mine spoil area which was surface mined from the late 1950's through the 1960's. The operation stripped two coal seams, the Davis and the overlying DeKoven seams in the Spoon Formation (Fig. 4). These two coals are separated by 5 to 12 feet of black, fissile shale containing 12% pyritic sulfur. In the absence of neutralizers such as limestone, as little as 1% pyritic sulfur can produce AMD contamination. Due to irregularities in the stripping operation, this shale is scattered rather evenly throughout the mine spoil. As a result, the Palzo site is producing some of the most toxic AMD in the mid-continent region. There have been pH readings as low as 1.8 recorded at this site. The DeKoven coal is capped by another channel sand, the Palzo Sandstone, which is much like the Vergennes seen at Stop #1 and may, in fact, be its lateral equivalent. The Palzo contains up to 5% pyritic sulfur in places.

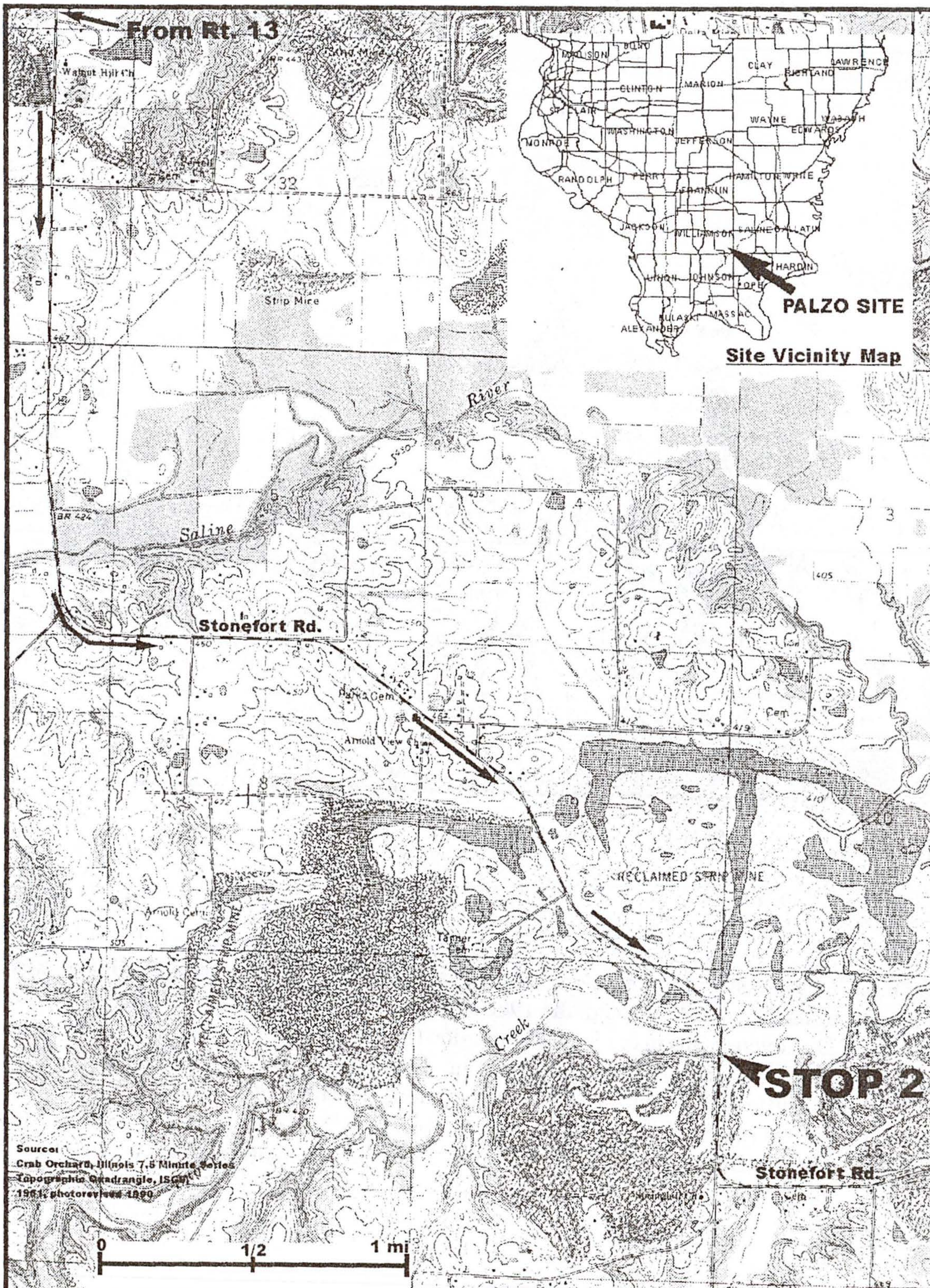

FIGURE 9 - Palzo Site

The relatively impermeable, north-northeast dipping underclay beneath the stripped Davis coal serves as an aquitard (Fig. 10). Groundwater flow is in the same direction and discharges into Sugar Creek along the north edge of the site as a series of AMD seeps several feet above the stream surface elevation. A portion of the AMD flows through the lower 20 feet of a gully after emerging as a seep. This gully is actually a pre-existing breach in a narrow upland remnant, which separates the adjacent highwall from Sugar Creek. Seepage of AMD through joints in the Palzo Sandstone can be seen at several places along the south bank of the stream.

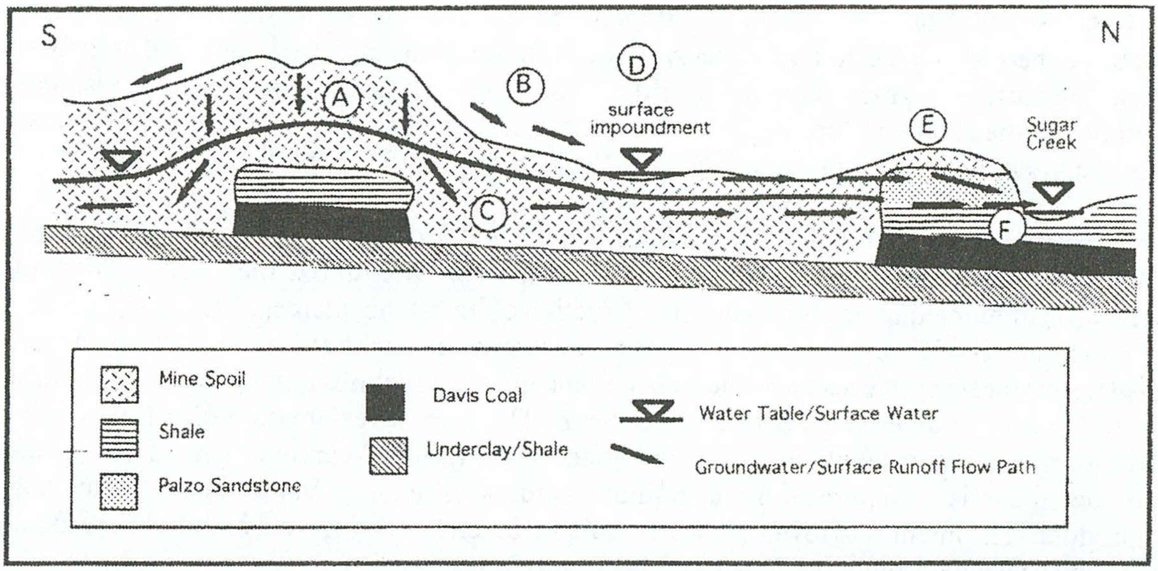

Figure 10 – Schematic N – S cross section through the Palzo site illustrating the two sources of AMD, A: infiltration and recharge to the water table, B: surface runoff and interflow following storm events, C: groundwater flow (base flow), D: surface impoundment fed by (B), E: pond overflow and AMD flow into Sugar Creek following storm events, F: groundwater seepage of AMD through joints/fractures in Palzo Sandstone and Sugar Creek.

More than 30 years of seepage and surface runoff have produced a thick build-up of iron hydroxides ("yellow boy") below the mouth of the gully. This build-up is reminiscent of travertine terracettes seen at some hot springs. In addition to the ubiquitous "yellow boy", acid sulfate salts appear as blotchy yellow and whitish precipitates on clast surfaces. They precipitate by evaporation of extremely low pH acid mine drainage, and play an important role in the generation of additional AMD at the Palzo site. Precipitation of these salts in pore spaces within scattered cobbles of Palzo Sandstone adjacent to the gully has caused them to partially disintegrate via "grussification". This weathering phenomenon is only observed around active AMD seeps.

Roughly $10,000,000 has been spent on reclamation efforts at the Palzo site over the past 25 years. Although much of the site has been regraded and revegetated, AMD still contaminates Sugar Creek. Recent investigations by the AMLRD suggest that there are two distinct sources of AMD at the site - a groundwater (phreatic) source, and a surface runoff/interflow (vadose) source. In the former case, water percolating down through the shallow subsurface zone of active pyrite oxidation becomes increasingly acidified. Once it reaches the water table, little more acidification is thought to take place. This AMD emerges as seepage into the lower reaches of the gully, marked by a knickpoint about 20 feet upstream from its mouth. It also seeps through the outcropping sandstone adjacent to the stream. This base flow seepage (pH=2.7-5.7) occurs year-round and is, by volume, the major source of acidity to Sugar Creek. The other source is from higher elevation seeps in the unsaturated zone which are active only for a few days following a large storm event. These seeps are best seen along the west side of the site. Rapid infiltration is funneled into a network of interconnected subhorizontal megapores or voids which exit along upper valley slopes. Such networks are common on mine spoil piles and have been called "pseudokarst". Indications of pseudokarst at the site, besides the vadose zone seeps, are numerous "swallow" holes in the spoil surface. Surface runoff enters these holes and rapidly fills the subsurface conduits, dissolving acid sulfate salts precipitated there following the previous storm event. This "stored" acidity produces a slug of extremely acid water (pH=2.4-3.4) which exits at the seeps and collects in surface impoundments such as the one about 250 feet upstream from the gully. These impoundments, constructed during a previous reclamation phase, are above the water table and only receive input following storms. Periodic pond overflows enter Sugar Creek and further degrade its water quality. The impoundment above the gully was designed to add alkalinity to the AMD by forcing flow through a gabion basket system filled with limestone. As can be seen, the system has long since clogged with "yellow boy" and is completely ineffective.

Previous attempts to control AMD contamination at the Palzo site have focused on adding alkalinity to the surface and shallow subsurface flow systems in an attempt to neutralize the acidity. These include surface application of municipal sewage sludge, construction of limestone intercept trenches downslope from seeps, and construction of limestone gabion impoundment structures in drainageways. None of these techniques have been completely successful. The trenches and gabion structures quickly clog with hydrous iron oxides and AMD flow is diverted over or around them. The current reclamation effort emphasizes decreasing infiltration to the water table by constructing an "impermeable" cap over part of the recharge area. The constructed cap is a mixture of mine spoil and scrubber sludge, a fine-grained alkaline coal combustion by-product. The intent is to lower the water table sufficiently to eliminate, or at least substantially decrease, base flow seepage through the upland remnant into Sugar Creek.

Stop #3 - Will Scarlet Site

Our final stop is the Will Scarlet mine site in southeastern Williamson County (Fig. 11). This is a large, 2,500-acre abandoned surface mine which, as at Palzo, stripped the Davis and DeKoven coal seams. The areally extensive spoil ridges and piles are only spottily vegetated and are highly erosive. AMD generated on and within the spoil finds its way into final cut lakes, inter-ridge depressions and lowland flats, and finally to the South Fork of the Saline River, where it renders a 25 mile stretch of the river "not supportive of aquatic life" according to the Illinois E.P.A. The same two systems of AMD generation discussed at the Palzo site are probably operating here as well.

Interestingly, many acidic lowland wet areas at Will Scarlet and other sites contain dense stands of vegetation. These environments foster growth of a tall, distinctive, acidophilic type of reed called *Phragmites sp.* Stands of *Phragmites* are especially common along roadside ditches draining AMD impacted areas, to the exclusion of other types of vegetation.

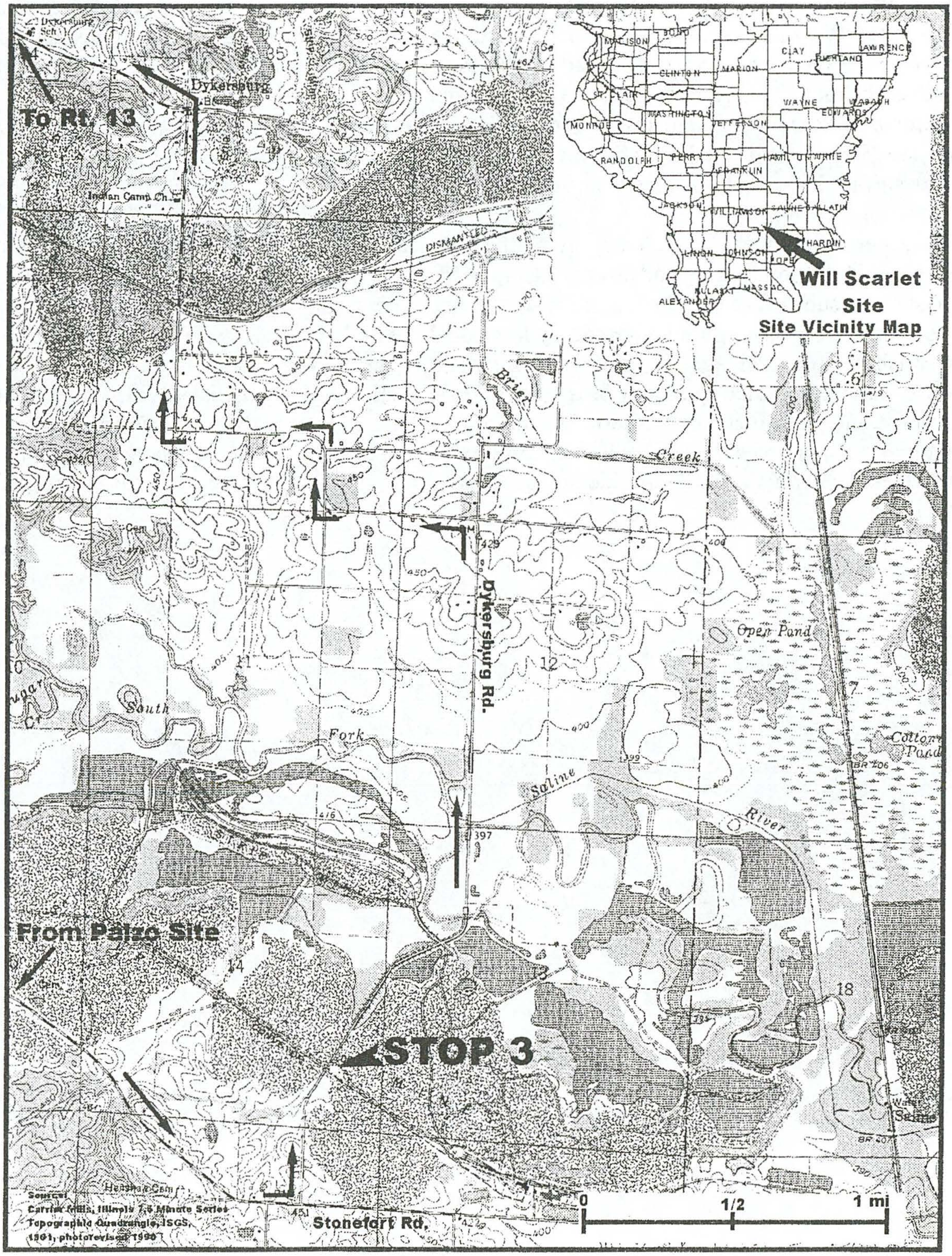

FIGURE 11 - Will Scarlet Site

Due to its size, reclamation at Will Scarlet is proceeding in several phases, each addressing a small portion of the site. We will be crossing one such area in which sediment from acidic spoil has aggraded within a drainageway on the east side of the road and blocked a culvert under the road. As a result, AMD is trapped south of the road. This contaminates the groundwater system and drives AMD northward into an area called Bulltown Bottoms, a 600 acre lowland containing several acid lakes. The aggraded sediment is the same as that covering the "kill zone" at Tab/Simco. Precipitated "yellow boy" in the pore spaces of the sediment and on its surface has locally formed a surface crust on the sediment.

The general approach to reclamation at this site involves(1) decreasing infiltration into the spoil, (2) controlling spoil erosion and promoting rapid drainage, (3) adding alkaline materials to the spoil surface and shallow subsurface to help neutralize acidic pore waters, and (4) establishing a viable vegetative cover. The first two objectives are addressed by large-scale regrading of the spoil to eliminate depressions and establish positive drainage. Erosion control structures and rip-rap channels are provided where needed. Portions of the regraded spoil may be used to fill in acid lakes. Alkalinity is provided by application of coal combustion by-products such as scrubber sludge, cement kiln dust or fly ash to the regraded surface. These materials are applied either by shallow incorporation (discing) or as a surface layer. Mine spoils amended with these materials usually provide an acceptable medium for plant growth with the proper addition of fertilizers.

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