MINERALOGICAL ALTERATIONS OF SOIL IRRIGATED WITH ACIDIC MINE WATER IN THE ALAMOSA RIVER BASIN

by

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INTRODUCTION

The headwaters of the Alamosa River originate in the San Juan Mountains, a world class ore-bearing range located to the west of the San Luis Valley. The Alamosa River naturally receives large amounts of heavy metals and acidity from the watershed it drains, but it is also receives the majority of the drainage from the Summitville Gold mine which introduces additional heavy metal-laden and highly acidic water. This could lead to dissolved and particulate metal loading at concentrations greater than background conditions. Downstream of the Terrace Reservoir, the pH of the Alamosa River has been reported to range from 4.2 to 7.0 with no measurable alkalinity (Erdman and Smith, 1996.) The metal loading data for the river shows high concentrations of cobalt (6-13 µg/L), copper (60-350 µg/L), zinc (150-190 µg/L), manganese (360-520 µg/L) and nickel (8-12 µg /L) (Erdman and Smith, 1996.) Smith and others (1995) concluded that there is a significant relationship between the pH of irrigation water and certain metal concentrations. As acidity increases, metal concentrations of copper, manganese and zinc increase.

In contrast, other irrigation waters such as the Rio Grande River and ground water have pH values ranging from 8.8-10.0 and very low concentrations of metals (Erdman and Smith, 1992.) It is common practice in the Alamosa River Basin, downstream of the Terrace Reservoir, to irrigate fields with Alamosa River water as well as Rio Grande River water and ground water.

The soils in the Alamosa Basin are formed over an alluvial outwash from the Platoro and Summitville calderas (Plumlee et al., 1992.) Weathering of the igneous mafic rock in the outwash results in soils which are alkaline with high natural acid buffering capacities (Plumlee et al, 1992.) Over the past decade, the water quality of the Alamosa River has degenerated due to increased mining activity in the 1980's at the Summitville Mine (Erdman and Smith, 1996.) Since the mine closed in 1992, the mine site was declared a United States Environmental Protection Agency (USEPA) Superfund Site. A study of the mineralogy and chemical characteristics of agricultural soils of the Alamos River Basin fills missing data gaps for the USEPA Risk Assessment Analysis of the Summitville Gold mine. The purpose of this study is to determine the mineralogical changes of the soils as a result of the addition of acidic waters to evaluate the long term buffering capacity of the soils. This paper will focus on experimental design and initial field observations from the Alamosa River Basin agricultural soils which have been subjected to a variety of water sources and irrigation practices.

EXPERIMENTAL DESIGN

This study is divided into two phases, Phase I- the Reconnaissance Survey and Phase II- the Detailed Study. This paper will only deal with Phase I, the Reconnaissance Survey. The Phases I research work is conducted across a single soil series, the Graypoint Series of the Alamosa River Basin. The Graypoint Series, classified as a fine-loamy over sandy or sandy-skeletal, mixed, frigid Typic Haplargid, is the dominate soil series in the area (The Soil Survey Staff, 1974.) Phase I looks at six levels of management across the Graypoint series in Conejos County near Capulin, Colorado: (1) virgin soil-never irrigated nor cropped, (2) irrigated and cropped prior to but not after 1984,

(3) flood irrigated with Rio Grande river water and/or deep groundwater and cropped with alfalfa, (4) sprinkler irrigated with Rio Grande river water and/or deep groundwater and cropped with alfalfa, (5) flood irrigated with Alamosa River water and cropped with alfalfa, and (6) sprinkler irrigated with Alamos River water and cropped with alfalfa. The study was initiated in the Spring of 1996, and the Phases I final report will be released to the public by the Colorado Department of Health and Environment December, 1996.

SAMPLING

Six sites were chosen in August, 1995 in the Alamosa River Basin. Each site represents one of the six management schemes. Permission was obtained from local growers before entering the fields to take samples. At each field a pit was dug by backhoe. The soil profile was described using USDA Soil Survey techniques and classified according to the Keys to Soil Taxonomy (The Soil Survey Staff, 1974.) At each site an additional 4 satellite pedons were sampled, one located at each corner of the pit, 10 meters away at a 45 degree angle. The 4 satellite pedons are being used for replication for the first two horizons of the model pedon. After the description of the profile, samples were taken from each horizon for bulk soil analysis, rock identification, carbonate and oxide concretion identification, and thin section analysis. Chemical and mineralogical analyses are currently being conducted.

SOIL PROFILE DESCRIPTIONS
Graypoint Series

SITE 1

Treatment: virgin soil
Geomorphic position: nearly level stream terrace
Physiography: mountain valley (0-1% slope)
Elevation ~7720 ft.
Drainage class: well drained
Erosion: slight Runoff: none to slight
Classification: loamy- skeletal over sandy skeletal, mixed, frigid, Typic Calciargid
Diagnostic horizons: 11-34 cm, argillic; 34-163 cm, calcic
Profile facing east described in sun

A--0 to 11 cm; gravelly sandy loam; brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, non sticky and non plastic; many fine roots throughout; no effervescence; 25% gravels, 2% cobbles; clear smooth boundary.
Bt--11to 34 cm; very gravelly sandy clay loam; brown (7.5YR 4/4) moist; weak medium subangular blocky structure; soft very friable, slightly sticky and slightly plastic; clay skins- common thin patchy on ped faces; many fines and few medium roots throughout; no effervescence; 45% gravels, 5% cobbles; clear wavy boundary.

2BCk1--34 to 49 cm; extremely gravelly sand; brown (10YR 5/3) moist; single grained; loose; non sticky and non plastic; common fine roots throughout; carbonates - none in matrix, very thin pendant coatings (1-2 mm) on clasts; slight effervescence; 65% gravels, 5% cobbles; clear wavy boundary.

2BCk2--49 to 91 cm; extremely gravelly sand; brown (10YR 5/3) moist; single grained; loose; non sticky and non plastic; few fine roots throughout; carbonates - none in matrix, very thin pendant coatings (1-2 mm) on clasts (slightly greater concentration than 2BCk1); slight effervescence; 60% gravels, 15% cobbles, 3% stones.

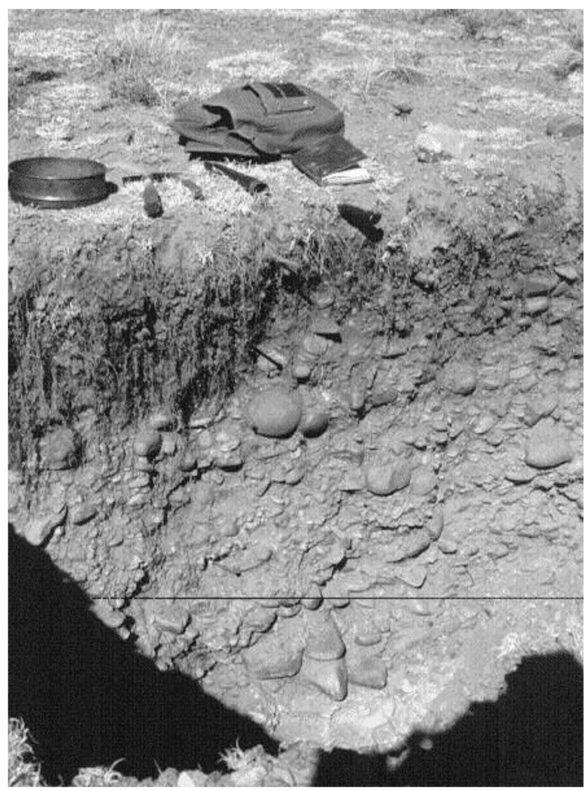

Figure 1. Site 1 - virgin soil profile.

SITE 2
Treatment: irrigated and cropped prior to but not after 1984
Geomorphic position: nearly level stream terrace
Physiography: mountain valley (0-1% slope)
Elevation ~7750 ft.
Drainage class: well drained
Erosion: slight Runoff: none to slight
Classification: loamy- skeletal over sandy skeletal, mixed, frigid, Typic Calciargid
Diagnostic horizons: 23-42 cm, argillic; 42-81+ cm, calcic
Profile facing east described in sun
Site 5 appears to have been subjected to severe disturbance, possible erosion.

Ap-- 0 to 23 cm; very gravelly sandy clay loam; brown (7.5YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and non plastic; common fine roots throughout; no effervescence; 30% gravels; 5% cobbles; clear wavy boundary.

Bt--23 to 42 cm: very gravelly sandy clay loam; brown (7.5YR 4/4) moist; weak subangular blocky structure; soft, very friable, slightly sticky and non plastic; common fine and few very fine roots throughout; no effervescence; 50% gravels, 5% cobbles; clear wavy boundary.

2BCk1--42 to 81 cm; extremely gravelly sand; brown (7.5YR 5/4) moist; single grained; loose; non sticky and non plastic; common fine roots throughout; carbonates - none in matrix, pendant coatings on clasts; slight effervescence; 60% gravels, 25% cobbles; clear wavy boundary.

2BCk2--81+ cm; extremely gravelly sand; brown (7.5YR 4/2) moist; single grained; loose non sticky and non plastic; few very fine roots throughout; carbonates - none in matrix, pendant coatings on clasts (slightly greater concentration than 2BCk1); slight effervescence; 70% pebbles, 10% cobbles; gradual wavy boundary.

Figure 2. Site 2 - pre-1984 soil profile.

SITE 3
Treatment: flood- irrigated with Rio Grande river water and/or deep ground water
Geomorphic position: nearly level stream terrace
Physiography: mountain valley (0-1% slope)
Elevation ~7675 ft.
Drainage class: well drained
Erosion: slight Runoff: none to slight
Classification: loamy- skeletal over sandy skeletal, mixed, frigid, Typic Calciargid
Diagnostic horizons: 27-45 cm, argillic; 27-87+ cm, calcic
Profile facing east described in sun

Ap--0 to 27 cm; gravelly heavy sandy loam; brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and non plastic; common fine and few coarse roots throughout; no effervescence; 15% gravels, 5% cobbles; abrupt smooth boundary.

Btk--27 to 45 cm; very gravelly sandy clay loam; brown (7.5YR 4/2) moist; moderate subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; many fine roots throughout; carbonates- disseminated, concentrated toward bottom of horizon; slight effervescence; 45% gravels, 10% cobbles; clear wavy boundary.

Bk--45 to 60 cm; extremely gravelly sandy loam; brown (10YR 4/3) moist; weak subangular blocky structure; slightly hard, very friable, slightly sticky and non plastic; common, very fine roots throughout; strong effervescence; 70% gravels, 5% cobbles; clear wavy boundary.

2BCk1--60 to 87 cm; extremely gravelly sand; brown (10YR 4/3) moist; single grained; loose; non sticky and non plastic; few coarse and few fine roots throughout; carbonates disseminated in matrix, pendant coatings on clasts; slight effervescence; 75% pebbles, 10% cobbles; gradual wavy boundary.

2BCk2--87+ cm; extremely gravelly sand; brown (10YR 5/3) moist; single grained; loose; non sticky and non plastic; few fine and very fine roots throughout; carbonates - pendant coatings on clasts; slight effervescence; 70% pebbles, 15% cobbles.

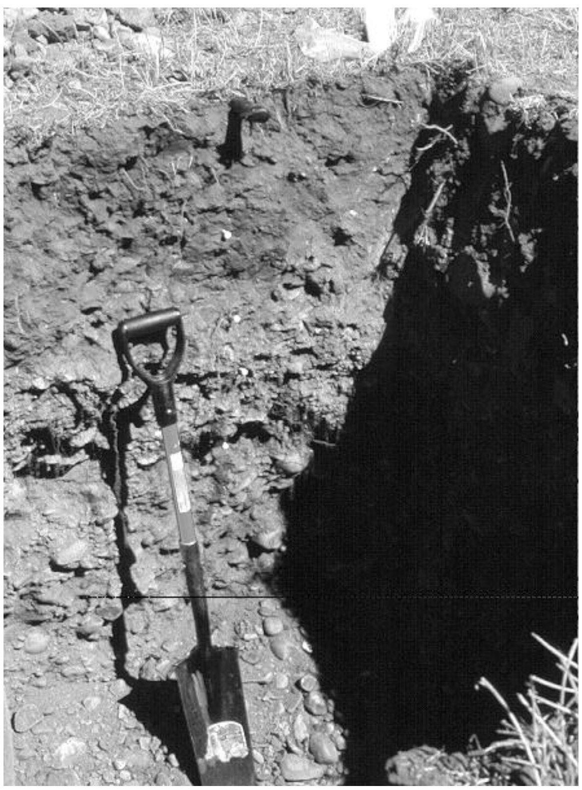

Figure 3. Site 3 - Rio Grande flood irrigated soil profile.

SITE 4

Treatment: sprinkler-irrigated with Rio Grande river water and/or deep ground water
Geomorphic position: nearly level stream terrace
Physiography: mountain valley (0-1% slope)
Elevation ~7675 ft.
Drainage class: well drained
Erosion: slight Runoff: none to slight
Classification: loamy- skeletal over sandy skeletal, mixed, frigid, Typic Calciargid
Diagnostic horizons: 27-42 cm, argillic; 27-104 cm, calcic
Profile facing east described in sun

Ap--0 to 27 cm; gravelly cobbly sandy clay loam; brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and non plastic; many very fine and few fine roots throughout; no effervescence; 40% gravels, 40% cobbles; clear smooth boundary.

Btk--27 to 42 cm; extremely cobbly sandy clay loam; brown (7.5YR 4/4) moist; weak subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; few fine roots throughout; carbonates- very few soft powdery masses in matrix, many pendant coatings on clasts; strong effervescence; 40% gravels, 35% cobbles; clear wavy boundary.

Bk1--42 to 74 cm; extremely gravelly sandy loam; brown (7.5YR 4/4) moist; single grained; loose; non sticky and non plastic; common fine roots throughout; carbonates- very few soft powdery masses in matrix, many pendant coatings on clasts; strong effervescence; 50% gravels, 3% cobbles; clear wavy boundary.

2Bk2--74 to 104 cm; extremely gravelly sand; brown (7.5YR 4/4) moist; single grained; loose; non sticky and non plastic; few fine roots throughout; carbonates- very few bridging sand grains in matrix, many pendant coatings on clasts; slight effervescence; 65% pebbles, 10% cobbles; gradual wavy boundary.

2BC--104+ cm; extremely gravelly sand; reddish brown (5YR 4/3) moist; single grained; loose; non sticky and non plastic; few fine roots throughout; few distinct iron oxide mottles (5YR 6/6); non effervescence; 70% pebbles, 15% cobbles, 5% stones.

Figure 4. Site 4 - Rio Grande sprinkler irrigated soil profile.

SITE 5

Treatment: flood-irrigated with Alamosa River water
Geomorphic position: nearly level stream terrace
Physiography: mountain valley (0-1% slope)
Elevation ~7770 ft.
Drainage class: well drained
Erosion: slight Runoff: none to slight
Classification: loamy- skeletal over sandy skeletal, mixed, frigid, Typic Torriorthent
Diagnostic horizons: cambic
Profile facing east described in sun

Ap--0 to 28 cm; gravelly sandy clay loam; reddish brown (5YR 4/3) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine roots throughout; no effervescence; 25% gravels, 5% cobbles; abrupt smooth boundary.

Bw1--28 to 57 cm; extremely gravelly sandy loam; reddish brown (5YR 4/3) moist; single grained; loose; non sticky and non plastic; few very fine roots throughout; no effervescence; 70% gravels, 3% cobbles; clear smooth boundary.

Bw2--57 to 79 cm; extremely gravelly loam; yellowish red (5YR 5/6) upper half of the horizon and reddish brown (5YR 4/3) moist; single grained; soft, very friable, slightly sticky and non plastic; common medium and very fine roots throughout; no effervescence; 65 %gravels, 3% cobbles, 5% stones; clear wavy boundary.

2Bw3--79 to 108 cm; extremely gravelly sand; dark reddish brown (5YR 3/3) moist; single grained; loose; non sticky and non plastic; few fine roots throughout; iron and manganese staining on coarse fragments; no effervescence; 80& pebbles, 5% cobbles; gradual wavy boundary.

2Bw4--108+ cm; extremely gravelly sand; dark brown (7.5YR 3/2) moist; single grained; loose; non sticky and non plastic; few very fine roots throughout; very thin carbonate coatings on coarse fragments (unreactive) no effervescence; 70% pebbles, 20% cobbles.

Figure 5. Site 5 - Alamosa flood irrigated soil profile.

SITE 6
Treatment: sprinkler-irrigated with Alamosa River water
Geomorphic position: nearly level stream terrace
Physiography: mountain valley (0-1% slope)
Elevation ~7770 ft.
Drainage class: well drained
Erosion: slight Runoff: none to slight
Classification: loamy- skeletal over sandy skeletal, mixed, frigid, Typic Torriorthent
Diagnostic horizons: cambic
Profile facing east described in sun
Plowing to 33 cm could have destroyed the argillic horizon, resulting in classification of the Dunul Series rather than the Graypoint Series.

Ap--0 to 33 cm; very gravelly sandy clay loam; brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and non plastic; common fine roots throughout; no effervescence; 40% gravels, 10% cobbles and 5% stones; clear smooth boundary.

Bw1--33 to 59 cm; very gravelly sand; dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky to massive structure; loose; non sticky and non plastic; common fine roots throughout; no effervescence; 65% gravels, 10% cobbles, 2% stones; clear wavy boundary.

2Bw2--59 to 87 cm; extremely gravelly sand; dark grayish brown (2.5YR 4/2) moist; massive; loose; non sticky and non plastic; common fine roots throughout; very few faint carbonates (variegated), slight effervescence; 70% gravels; 15% cobbles; gradual wavy boundary.

2Bw3--87 to 120 cm; extremely gravelly sand; dark grayish brown (2.5YR 4/2) moist; single grained; loose; non sticky and non plastic; few very fine roots throughout; very few faint carbonates (variegated), slight effervescence; 80% gravels; 5% cobbles; gradual wavy boundary.

2BC--120+ cm; extremely gravelly sand; dark grayish brown (2.5YR 4/2) moist; single grained; loose; non sticky and non plastic; few very fine roots throughout; very few faint carbonates (variegated), slight effervescence; metal staining reducing zones throughout horizon; 80% gravels, 5% cobbles, 3% stones.

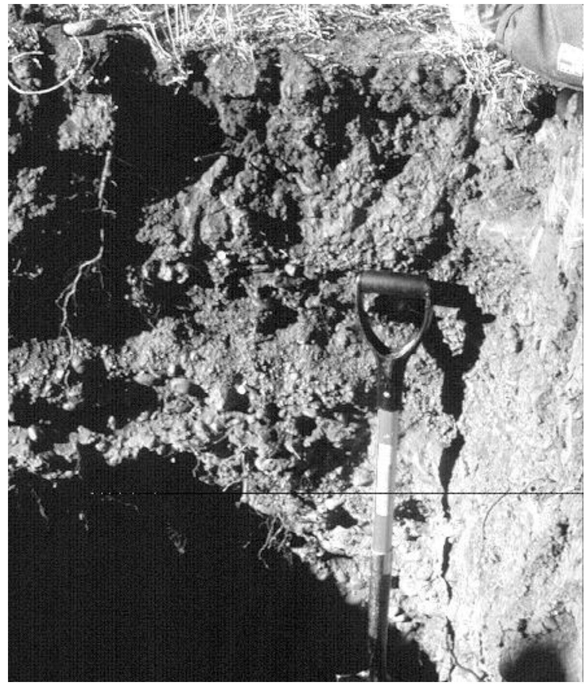

Figure 6. Site 6 - Alamosa sprinkler irrigated soil profile.

DISCUSSION OF FIELD OBSERVATIONS

The degree of weathering in the Graypoint series differs according to which of the six different management schemes the soil is under. Under virgin conditions (site 1), soil formation and weathering are assumed to occur at natural rates typical of arid environments. These weathering processes have slowly developed an argillic horizon from illuviation of clay from the surface. Carbonates have accumulated on the undersides of rock clasts at and below 34 cm with increasing concentration down the soil profile. There are no carbonate concretions in the matrix. The rocks identified from this site show comparatively moderate weathering rinds and are still intact. Site 2 (irrigated and cultivated prior to but not after 1984) also has an argillic horizon and the remnants of a plowed surface horizon which has been subjected to severe disturbance and possible erosion. Carbonates are absent in the upper portion of the profile but can be found on the undersides of rockclasts at and below 42 cm as in site 1. The rocks identified from this site show larger weathering rinds than in site 1 and have some oxide staining but still are intact.

Site 3 and site 4 have greater carbonate accumulation than any of the other sites. This is likely due to the application of high pH irrigation waters moving through the soil profile. There are very few oxide stains on the rocks and weathering of the rocks is least in these two sites. Carbonates are disseminated throughout the matrix for the flood irrigated site (site 3). Under sprinkler irrigation, carbonates can be found in powdery masses within the matrix and as pendant coatings on clasts (site 4). Site 4 also shows the greatest effervescence closest to the surface presumably due to less leaching under sprinkler irrigation.

The greatest signs of weathering occur in sites 5 and 6. This is presumed to be due to the application of the acidic irrigation waters of the Alamosa River. In site 5 there is no accumulation of clay to as an argillic horizon. The high water volume of flood irrigation has moved the clay out of the profile as well as leached the matrix of any reactive carbonates. The undersides of clasts found lower down in the soil profile are covered with a thin white coating that appears to be carbonate but does not react with 1 M HCl. This coating may be silica that has been leached down through the soil profile. These coatings are currently being analyzed. The rocks identified at these two sites are heavily weathered and oxide stained. Iron and manganese staining is prevalent on all rock especially gravels and cobbles. Accelerated weathering compared to control soils, has caused the rocks to breakdown upon handling of the rocks many fall apart in the hand. Significantly larger weathering rinds are present at this site than in any of the other five sites.

Site 6 is also treated with Alamosa River water but through sprinkler irrigation. The lower volume application of acidic irrigation water under sprinklers has left thin coatings of carbonates on the undersides of clasts described as variegated in the soil profile description. As in site 5, site 6 does not have enough clay accumulation to have an argillic horizon. Also in the 2BC horizon rocks are heavily stained with iron and manganese oxides.

It is our observation that the use of Alamosa River water for irrigation has considerably altered the degree of weathering in the soils of the Alamosa River Basin. This is evident in the lack of carbonates in the profile when compared to soils irrigated with other sources of water, the increased iron and manganese staining on rocks, and the increased degradation of the rocks.

Other than field observations very few conclusions can be made at this time. Extensive chemical and physical analyses of the samples from each sites is being conducted in cooperation with Colorado School of Mines and Agro-Engineering of Alamosa, Colorado. Experiments are being conducted to determine the present state of the soils in the Alamosa River Basin and to predict the long-term acid buffering capacity of the soils. Modeling will be used to determine the annual acid and heavy metal loading that these soils will be able to withstand without further degradation. Finally, the study will help local agriculturists make better decisions on how to manage their fields when irrigating with Alamosa River water.

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