4.6. WISMUT PROJECT - UPDATE

At the November workshop, Mr. Hockley presented an overview of recent ARD-related work in the Ronneburg mining district of the former East Germany. Overheads used in the presentation are included herein. Also included is a draft copy of a paper that will be presented at ICARD 97. The paper provides more detail on remediation of the largest waste rock pile in the Ronneburg district. Three other papers related to the Wismut project will be presented at ICARD 97, and will provide more detail on other topics covered at the workshop.

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WASTE ROCK REMEDIATION ACTIVITIES IN THE RONNEBURG MINING DISTRICT

Daryl Hockley

John Chapman

Steffen Robertson & Kirsten (Canada) Inc.

Presented at the Fourth Annual B.C. ARD Symposium, Vancouver B.C., November 7-8, 1996

Rostock
Hamburg
Hannover
Berlin
Leipzig
Bonn
Gera
Dresden
Frankfurt
GERMANY
Munich

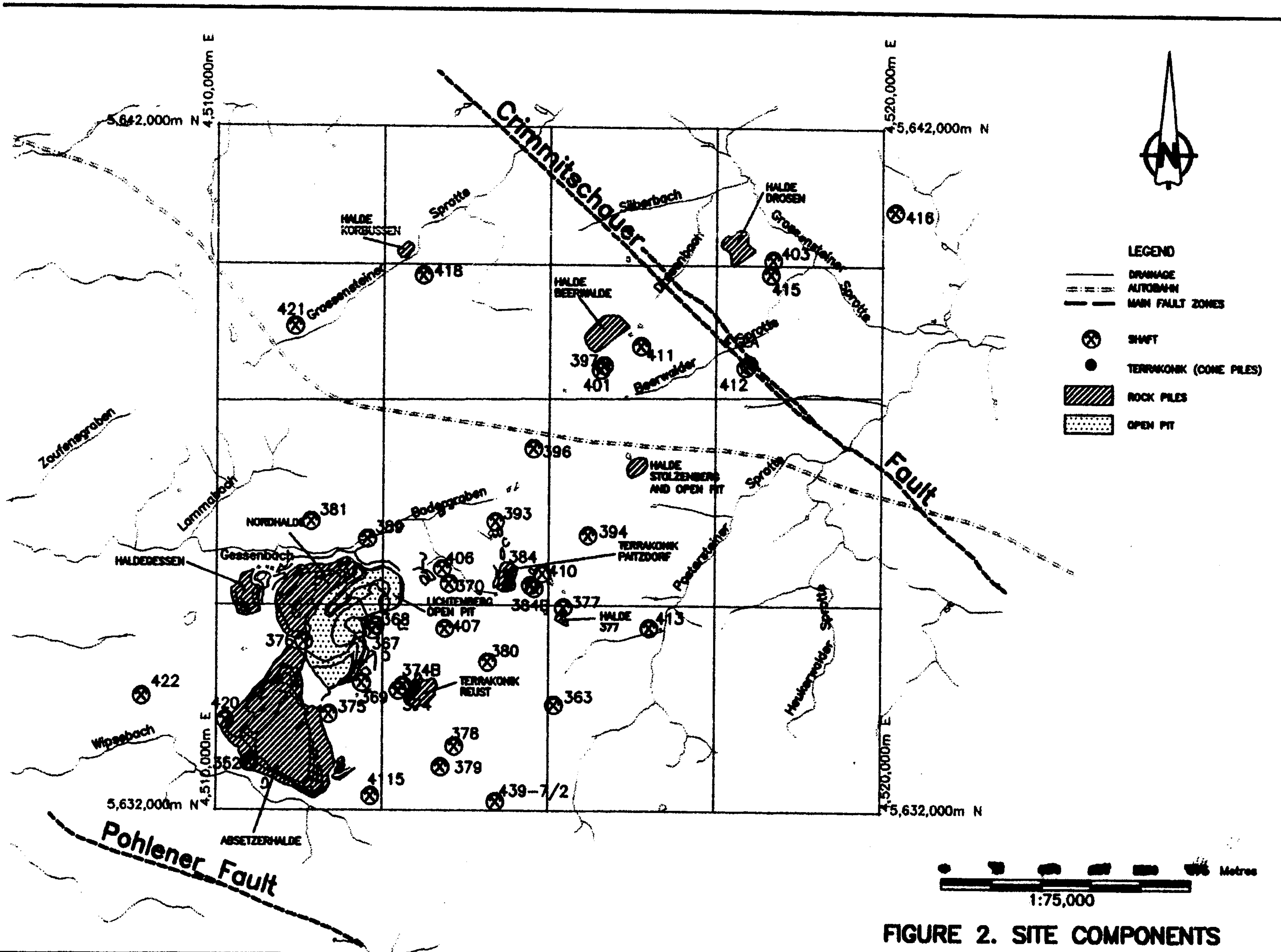


FIGURE 2. SITE COMPONENTS

Project History

Initial characterization

Drilling programs

Relocation of Gessenhalde

Relocation of Absetzerhalde

Review of options for other piles

Initial Characterization

Topography, Drainage, Habitation

Climate, Hydrology, Hydrogeology

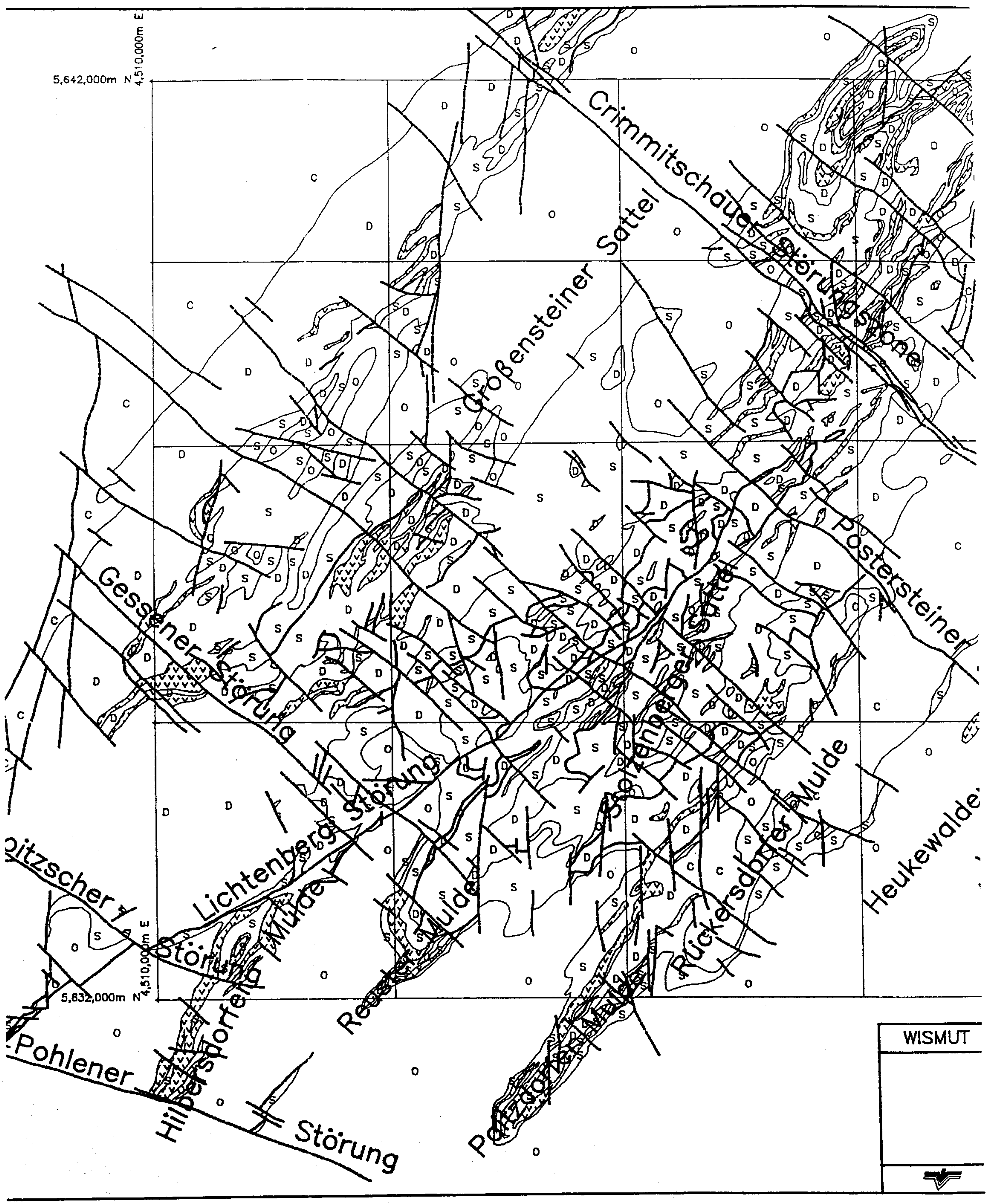
Geology, Mineralogy, Geochemistry

History of Mine Development

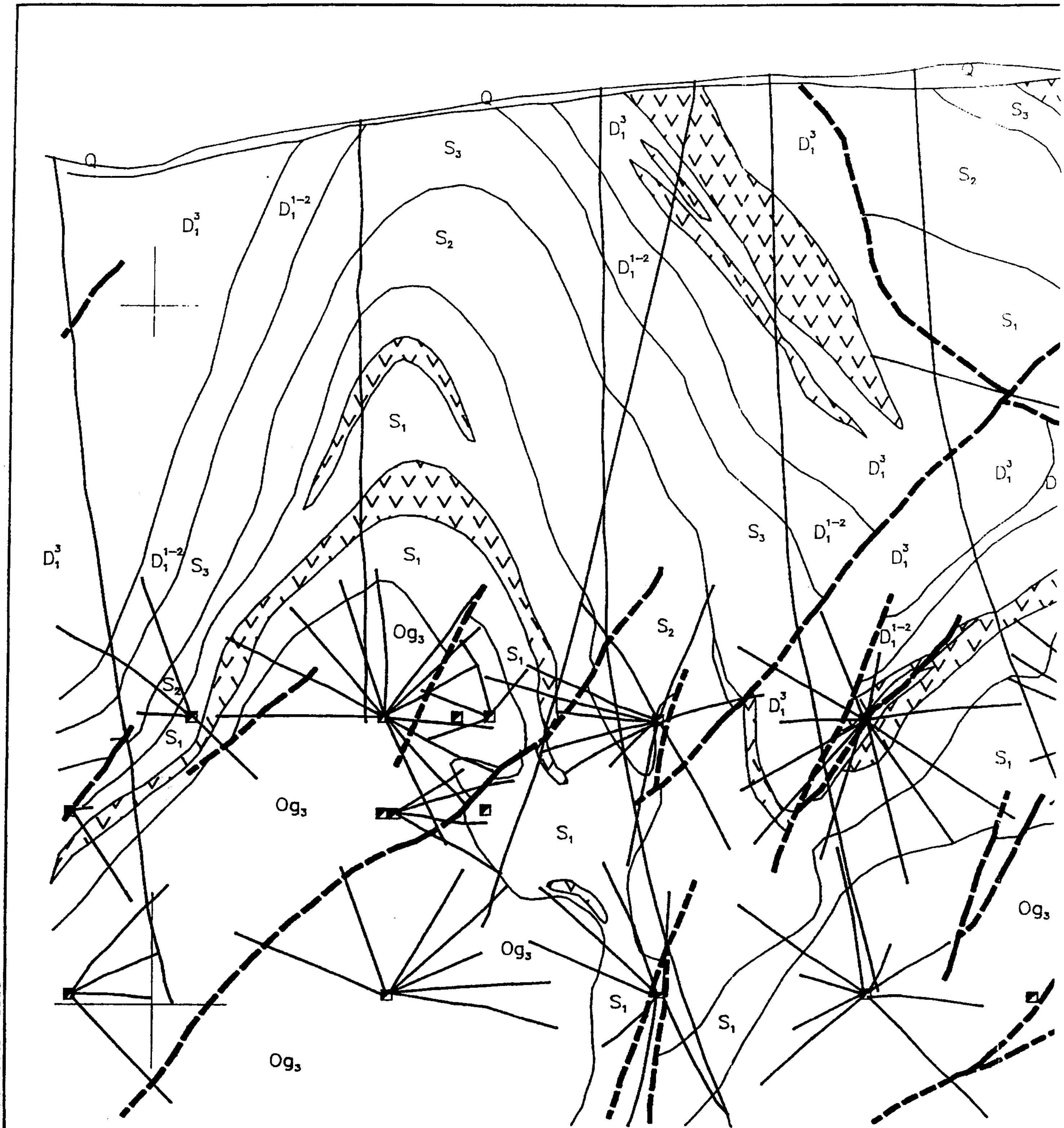
Exploration, U/G Mines, O/P Mines

Waste rock piles

Reclamation measures



5,642,000m N
4,510,000m E
5,632,000m N
4,510,000m E
Crimmitschauer Störungszone
Großensteiner Sattel
Postersteiner
Gessener Störung
Lichtenberg Störung
Lichtenberg Mulde
Störung
Pohlener
Störung
Hilbersdorfer Mulde
Rückersdorfer Mulde
Heukewalde
WISMUT



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Further Investigations

Gessenhalde Relocation

Absetzerhalde Relocation

Presented at the Fourth Annual B.C. ARD Symposium, Vancouver B.C., November 7-8, 1996

Drilling Programs

Name	Phase I Drillholes	Phase II 'Infill' Drillholes	TOTAL	Vol. Rock/ drillhole ($x10^6 m^3$/hole)
Absetzerhalde	22	25	47	1.40
Innenkippe	-	17	17	3.76
Nordhalde	16	7	23	1.18
Schmirchauer Balkon	-	10	10	1.20
Terrakonika Paitzdorf	10	-	10	0.76
Terrakonika Reust	8	8	16	0.39
Halde Beerwalde	9	-	9	0.50
Halde Drosen	10	-	10	0.35
Halde 4	*38	-	38	0.02
Halde Schact 377	*50	3	53	0.02
Halde Schact 381	7	-	7	0.06
Halde Korbussen	4	-	4	0.10
Halde 377	8	-	8	0.04

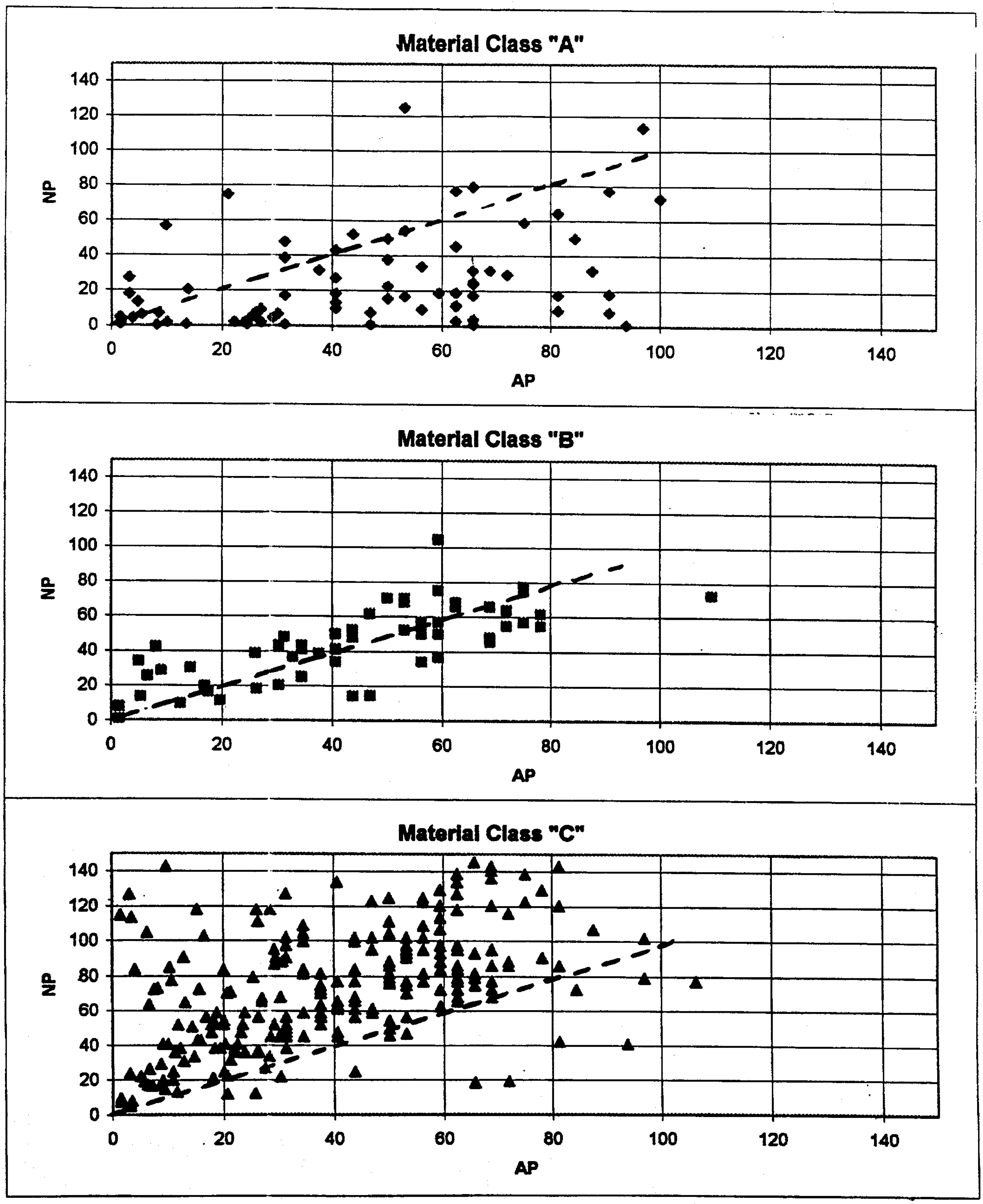
* Shallow depth ramcore drillholes

LABORATORY CLASSIFICATION TEST PROGRAM SUMMARY

Test Method	Rock Pile TEST PITS	SUBTOTAL 112
Laboratory Classification		
Whole Sample (-63 mm):		
Moisture Content		112
Chemical Analysis		112
CaO, MgO, CO_2, S^{2-}, SO_4		
Corg, Fe^{3+}/Fe^{2+},		
Th230, Ra226, Pb210, Unat		
Acid Soluble Al, As, Pb, Ni, Cu, Zn		112
Mineralogy		112
Acid Base Account ABA (modfied Sobek)		112
NAP (Coastech 92)		56
+20mm - 63mm		
Chemical Analysis		56
CO_2, S^{2-}, SO_4		
Fe^{3+}/Fe^{2+},		
Ra226, Unat		
Acid Soluble Al, Fe		56
+2mm -20mm		
Chemical Analysis		56
CO_2, S^{2-}, SO_4		
Fe^{3+}/Fe^{2+},		
Ra226, Unat		
Acid Soluble Al, Fe		56
-2mm		
Chemical Analysis		56
CO_2, S^{2-}, SO_4		
Fe^{3+}/Fe^{2+},		
Ra226, Unat		
Acid Soluble Al, Fe		56
- 20 mm		
Wet sieving		56
Sieve Analyses		56
Atterburg Limits (Index Properties)		28
Laboratory Behaviour		
Whole Sample (-63 mm)		
Saturated Columns		126
Saturated Columns with alkali addition		28
Humidity Columns		40

FIELD TEST LABORATORY ASSESSMENT PROGRAM SUMMARY

Test Method	HALDE TEST PITS	SUBTOTAL 112
Field Classification		
Paste pH		112
Paste Conductivity		112
Lithological description		112
Size Distribution		112
Soil description		112
Geochemical Tests		
- 20 mm		56
Modified NAP/NAG (2x)		112
Elution Std.		56
Ammonium Oxalate Elution		56
Paste pH/Cond.		56
-2 mm		
Modified NAP/NAG (4x)		224
Elution Std.		56
Ammonium Oxalate Elution		56
Paste pH/Cond.		56



NP - AP Characteristics of Samples Classified by Field Test Methods

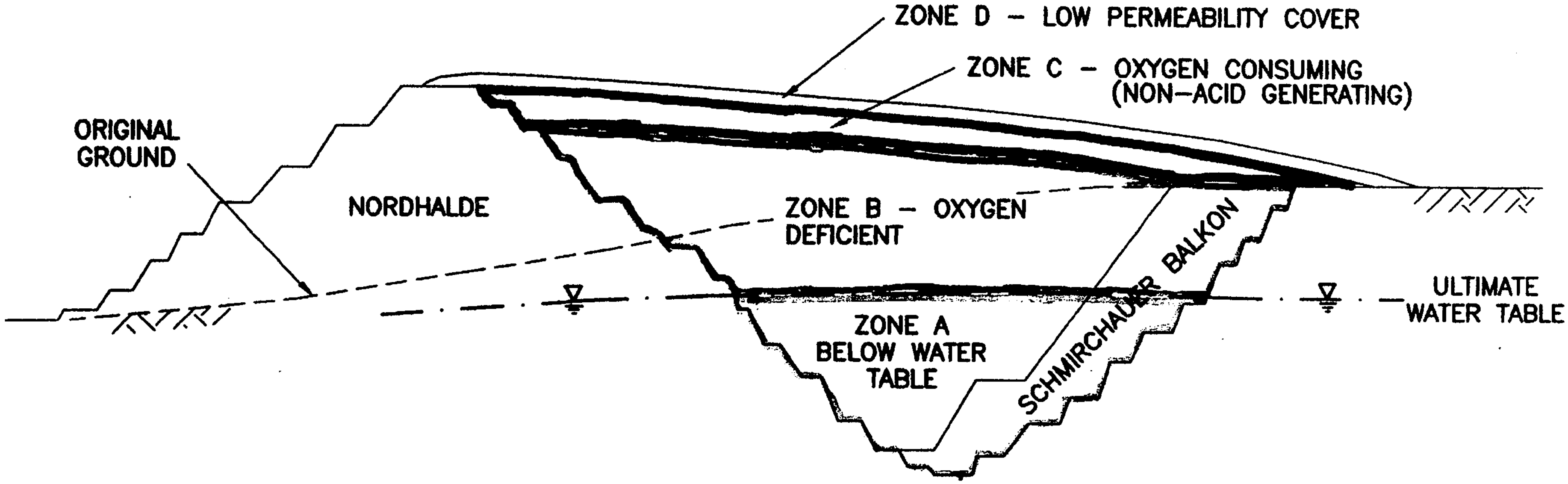


FIGURE 3 SCHEMATIC SECTION OF THE BACKFILLED LICHTENBERG PIT

Review of Options for Other Waste Rock Piles

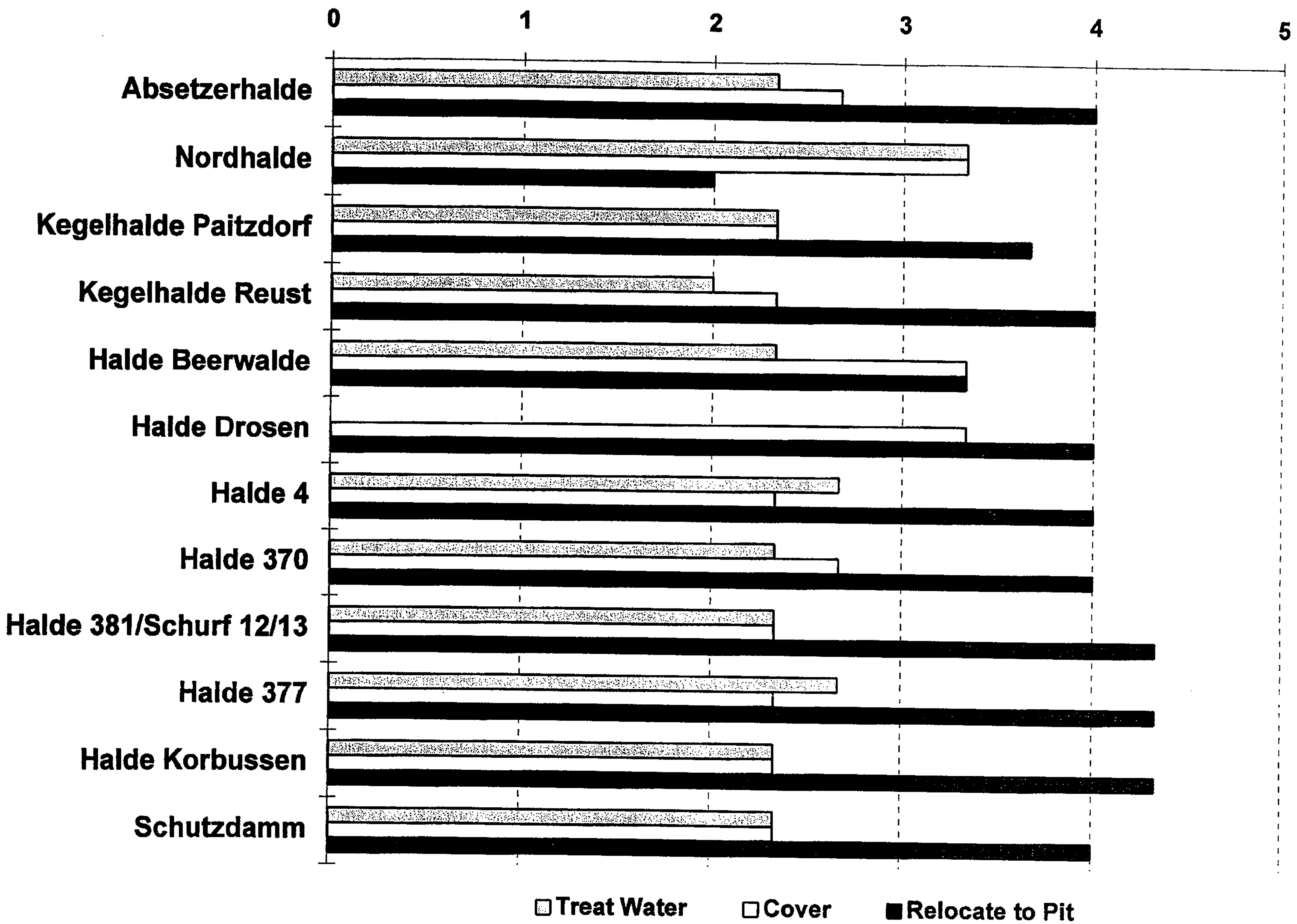
Top down approach

Evaluation matrix

Utility theory

Waste Rock Pile	*Cost Scores*			*Risk Scores*			*Public Acceptance Scores*		
	Treat Water	Cover	Relocate to Plt	Treat Water	Cover	Relocate to Plt	Treat Water	Cover	Relocate to Plt
Absetzerhalde	5	2	3	1	4	4	1	2	5
Nordhalde	5	3	1	2	3	2	3	4	3
Kegelhalde Paitzdorf	4	1	3	2	3	3	1	3	5
Kegelhalde Reust	3	1	3	2	3	4	1	3	5
Halde Beerwalde	5	3	1	1	4	4	1	3	5
Halde Drosen		3	3		3	4		4	5
Halde 4	4	1	3	2	3	5	2	3	4
Halde 370	3	1	3	2	3	5	2	4	4
Halde 381/Schurf 12/13	4	1	3	2	3	5	1	3	5
Halde 377	4	1	3	2	3	5	2	3	5
Halde Korbussen	3	1	3	2	3	5	2	3	5
Schutzdamm	4	1	3	2	3	5	1	3	4

Waste Rock Pile	*Weighted Total Scores*		
	Treat Water	Cover	Relocate to Pit
Absetzerhalde	2.3	2.7	4.0
Nordhalde	3.3	3.3	2.0
Kegelhalde Paitzdorf	2.3	2.3	3.7
Kegelhalde Reust	2.0	2.3	4.0
Halde Beerwalde	2.3	3.3	3.3
Halde Drosen	0.0	3.3	4.0
Halde 4	2.7	2.3	4.0
Halde 370	2.3	2.7	4.0
Halde 381/Schurf 12/13	2.3	2.3	4.3
Halde 377	2.7	2.3	4.3
Halde Korbussen	2.3	2.3	4.3
Schutzdamm	2.3	2.3	4.0


0
1
2
3
4
5
Absetzerhalde
Nordhalde
Kegelhalde Paitzdorf
Kegelhalde Reust
Halde Beerwalde
Halde Drosen
Halde 4
Halde 370
Halde 381/Schurf 12/13
Halde 377
Halde Korbussen
Schutzdamm
Treat Water
Cover
Relocate to Pit

Review of Options

Relatively simple matrix approach led to:

- *Clear decision for 12 of 14 piles*
- *Two alternatives for Nordhalde*
- *Two alternatives for Halde Beerwalde*

In situ Remediation of Halde Beerwalde

Two Waste Rock Piles

	Beerwalde	Drosen
Sulfide S	0.84%	0.63%
Carbonate	5.43%	4.96%
NP:AP	3.5	4.2
Sulphate	26,000 mg/L	2,800 mg/L

In situ Remediation of Nordhalde

Location of acid generating material well defined

Possibility for combination of cover and C-Zone

Integration with filling of pit

SRK

Presented at the Fourth Annual B.C. ARD Symposium, Vancouver B.C., November 7-8, 1996

RELOCATION OF WASTE ROCK TO THE LICHTENBERG PIT NEAR RONNEBURG, GERMANY

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Wolfgang Weise[4]

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Presented at the *Fourth International Conference on Acid Rock Drainage*, Vancouver British Columbia, June 1997

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ABSTRACT

The Absetzerhalde is a waste rock pile in the Ronneburg uranium mining district of the former East Germany. The pile contained approximately 65 million cubic meters of waste rock, much of which is acid generating. As part of the remediation of the Ronneburg district, waste rock from the Absetzerhalde is being backfilled into the adjacent Lichtenberg Pit. To limit contaminant release from the backfilled pit, acid generating material is being amended with quicklime (CaO) and placed below the future water table. Potentially acid generating rock is being placed above the water table but below the expected depth of oxygen penetration. Rock with an excess neutralization potential is being placed nearest the future ground surface. Investigations carried out to support the relocation program have included review of historical and geological information, drilling of boreholes and excavation of test pits, static and ABA tests, saturated column tests, unsaturated column tests, and lime addition tests. The requirement to identify different classes of waste rock, in order to relocate them to the proper level in the pit, led to the development of rapid field tests and a protocol for sampling, testing, and directing the backfilling and lime addition programs.

KEY WORDS: waste rock, acid generation, uranium, historical information, kriging, static tests, column tests, field tests, mapping, waste rock relocation, pit backfilling, lime addition, control program

INTRODUCTION

Uranium mining in the Ronneburg district of the former East Germany began in 1950 and lasted until shortly after German re-unification in 1991. The area is now the site of one of the world's largest mine closure projects (see Gatzweiler *et al.*, this volume). Figure 1 is a plan of the Ronneburg district. Shown on the plan are the Lichtenberg Pit and some of the sixteen waste rock piles.

One of the principal remediation activities in the Ronneburg district is the relocation of waste rock to the Lichtenberg Pit. In order to control the potential for acid generation, the waste rock is being placed in three zones, as shown in Figure 2:

- Rock that is already acidic, or that has a potential to generate acidic drainage, is placed in Zone A. To prevent the short term release of acidity that is already present in the rock, quicklime is added during the relocation. After groundwater recovery, Zone A will be below the water table, and the absence of oxygen will become the long term control on the potential for acid generation.
- Rock that has an uncertain potential to generate acidic drainage is placed in Zone B. It is expected that Zone B will be above the water table, but below the depth of oxygen penetration.
- Rock that has no potential to generate acidic drainage is placed in Zone C. Oxidation of sulphide minerals will occur in Zone C, but the oxidation products will be neutralized by reaction with the relatively abundant carbonates.

As Figures 1 and 2 show, the pit already contains two waste rock deposits, known as the Innenkippe and the Schmirchauer Balkon, which were produced from underground mining. The Gessenhalde, shown on surface in Figure 1 and in the pit in Figure 2, was a heap leach pile. It was relocated to the bottom of the pit between 1990 and 1995.

Currently, the largest of the waste rock piles, known as the Absetzerhalde, is being relocated. The Absetzerhalde initially contained 65 million cubic meters (approximately 120 million tonnes) of black shales, limestones and diabase ranging in age from Ordovician to Devonian. As in other waste rock in the Ronneburg district, the acid generating mineral is pyrite, present at concentrations of up to 7%. Dolomite and calcite are the principal neutralizing minerals, with total carbonate mineral contents of up to 35%. Uranium, radionuclides, and several heavy metals are the contaminants of concern. Typical seepage from the Absetzerhalde has a pH ranging from 1.5 to 3.1, sulphate concentrations from 7,000 to 25,000 mg/L, and uranium concentrations from 1 to 8 mg/L.

INVESTIGATION PROGRAMS

A series of investigations of the Ronneburg waste rock piles were completed to serve as the basis for the relocation program and other remediation activities. In brief, the investigations included:

- Review of available information about the geology, geochemistry, and construction history of each pile;
- Drilling, logging, and analysis of samples from 247 boreholes;
- Excavation, logging, and analysis of samples from 112 test pits;
- Comparison of several field and laboratory static test methods; and,
- Approximately 200 column tests.

In addition, conceptual designs, cost-benefit calculations, water quality predictions, and radiological and conventional risk predictions were prepared for each remediation alternative and each waste rock pile. The results were summarized in an evaluation matrix and multi-attribute utility analysis, (SRK 1995a, Wismut 1995a) For the Absetzerhalde, the clear conclusion was that it should be relocated to the Lichtenberg Pit.

Key results of the investigations are presented in the following sections, using the Absetzerhalde as an example.

REVIEW OF AVAILABLE INFORMATION

During operations, Wismut geologists created a detailed "Rock Catalogue" to list and describe all of the geological units encountered in each mining area. For each unit, the description included lithology, alteration, estimated mineralogical composition, and assay results. Comparison of the information from the rock catalogue, geologic sections, and production statistics allowed SRK (1994) and Wismut (1995) to estimate the mineralogical composition of each waste rock pile.

Under the assumption that pyrite is the sole acid generating mineral, and carbonates the only neutralizing minerals, estimates of the overall acid generating potential (AP) and neutralizing

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potential (NP) of each pile were obtained. The Absetzerhalde was estimated to have an average NP:AP ratio of 1.5.

DRILLHOLE INVESTIGATION

The drilling program was carried out in two phases, with the second phase consisting of infill drilling on some of the piles. The retrieved core was logged and composited in 2 m intervals, and samples were analyzed for carbonate, sulphide, sulphate, uranium, and various metals. A total of 66 boreholes were completed in the Absetzerhalde, to a maximum depth of 68 m. Over 1000 samples were analyzed.

AP and NP values were calculated for each drillhole interval. The NP:AP ratios were then compared with literature criteria to indicate the likely importance of acid generation:

- NP:AP < 1 was assumed to indicate a net acid generation potential;
- 1 < NP:AP < 3 was assumed to indicate an uncertain potential for net acid generation; and,
- NP:AP > 3 was assumed to indicate a net acid consumer.

The NP:AP ratios were plotted on section, along with construction boundaries available from historical data. A polygonal interpretation was completed, resulting in the volume estimates shown in Table 1.

Carbonate and sulphide contents between the drillholes were also interpolated using the method of Ordinary Kriging. In the Absetzerhalde, it was clear that construction had been in benches. Therefore, each bench was treated independently in the kriging. Semi-variograms were generated using all data from the bench, and the block values were estimated. After each block in each bench had been assigned an estimated carbonate and estimated sulphide content, the estimates were converted and compared to the NP:AP criteria.

Results of the kriging are compared to estimates from the polygonal interpretation in Table 1. As is clear from the table, the kriging estimates suggested that a higher proportion of the pile falls into the category of "uncertain" acid generation potential. The reason is that the kriging process tends to "smear" extreme values, producing estimates that are closer to the middle of the data range. Example kriging results are compared to subsequent field measurements below.

Table 1
ABA Classification of Material in the Absetzerhalde

	Class A NP:AP < 1	Class B 1 < NP:AP < 3	Class C NP:AP > 3
Volumes estimated by polygonal interpretation of drilling results and historical records (million m^3)	36.2	19.3	10.3
Volumes estimated by kriging of drillhole ABA data (million m^3)	31.1	26.1	1.0

TEST PIT SAMPLING AND STATIC TESTS

To retrieve undisturbed samples for laboratory testing, test pits were excavated to a depth of 5 m. Locations were selected, on the basis of the drilling program, to be representative of all common rock types. The tests pits were logged during excavation. From each test pit, approximately 300 kg of material was retrieved and stored in a warehouse.

Samples for the laboratory tests were obtained by coning and quartering the stored material. The sub-samples were then subjected to the series of tests shown in Table 2. The extensive program of static tests had two objectives. The first was to characterize the composition of the material. The second was to develop correlations between laboratory methods and simpler methods that could be used in the field to provide a rapid material characterization.

The scope of this paper does not permit a full discussion of the results of the static tests, but key results with respect to the Absetzerhale relocation are discussed below.

COLUMN TESTING

Table 2 summarizes the program of column tests that was carried out on the test pit samples. In general, there were two types of column tests: saturated or "hydrostatic" tests; and unsaturated or "infiltrative tests". The standard column was 60 cm high and 30 cm inside diameter, and contained approximately 40 kg of rock. Variations on the standard procedure included taller columns, shorter columns, and addition of quicklime to the rock.

Figures 3 and 4 illustrate two complexities particular to this site. The plot of sulphate vs. pH shows that it is possible to have very high sulphate concentrations without acid generation. The reason is the presence of dolomite as the dominant carbonate phase in some of the lithological units. Although the carbonate released by dolomite dissolution is effective in neutralizing acid, the magnesium caption does not react with sulphate until concentrations reach saturation of epsomite - a very soluble salt. The same phenomenon was observed in the field. Seepage from one rock pile with a high dolomite: calcite ratio remained neutral but exhibited sulphate concentrations of up to 30,000 mg/L. Figure 4 shows uranium concentrations vs. pH. Like other metals, uranium is very soluble under acidic conditions, confirming the importance of controlling acid generation. However, the figure shows that, once dissolved from its primary mineral phases, uranium can remain soluble at neutral pH.

On the basis of the column tests, together with analyses of water treatment costs and human health impacts that are beyond the scope of this paper, it was confirmed that the priority for the relocation program should be the control of acid generation. Control of sulphate and uranium were identified as secondary priorities, to be taken into consideration where acid generation is not a concern.

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Table 2
Laboratory Program for Test Pit Samples

Test Method	Reference	Number of Tests		
Field Classification Tests		Whole sample	- 20 mm fraction	-2 mm fraction
Paste pH and conductivity	SRK, 1995c	112		
NP reactivity	SRK, 1995c	112		
Lithology	Wismut in-house	112		
Size Distribution	DIN 4022	112		
Soil and Rock Description	DIN 4022 Part 1	112		
NAP/NAG	Miller 1990, Coastech 1992		112	224
Standard Elution	SRK, 1995c		56	56
Ammonium Oxalate Elution	McKeague & Day, 1965		56	56
Paste pH and conductivity	SRK, 1995c		56	56
Laboratory Classification Tests				
Moisture Content	DIN 18,121	112		
Seive Analyses	DIN 18,123	112		
Chemical analyses (CaO, MgO, Fe_2O_3, Fe(II), Fe(III), As, Cd, Co, Cu, Mo, Ni, Pb, U, Ra, Th, and radionuclides)	various methods	112	56	56
Acid Soluble Al, As, Pb, Ni, Cu, Zn		112	56	56
Mineralogy	various methods	selected samples		
ABA (modified Sobek and CO_3-NP)	Coastech, 1992	112	56	56
NAP	Coastech, 1992	112		
Atterburg Limits (Index Properties)	DIN 18,122		28	
Behaviour Tests				
Saturated Columns	SRK, 1995	112		
Humidity Columns	SRK, 1995	55		
Large Scale Oedometer	DIN 18,300	30		
Falling Head Permeability	DIN 18,130 (modified)	15		
Proctor Compaction	DIN 18,127	15		
Abration	ASTM C 131	15		
Wet-Dry Slaking	ASTM D4644	15		
Unsaturated Conductivity and Capillarity	Wismut in-house	5		

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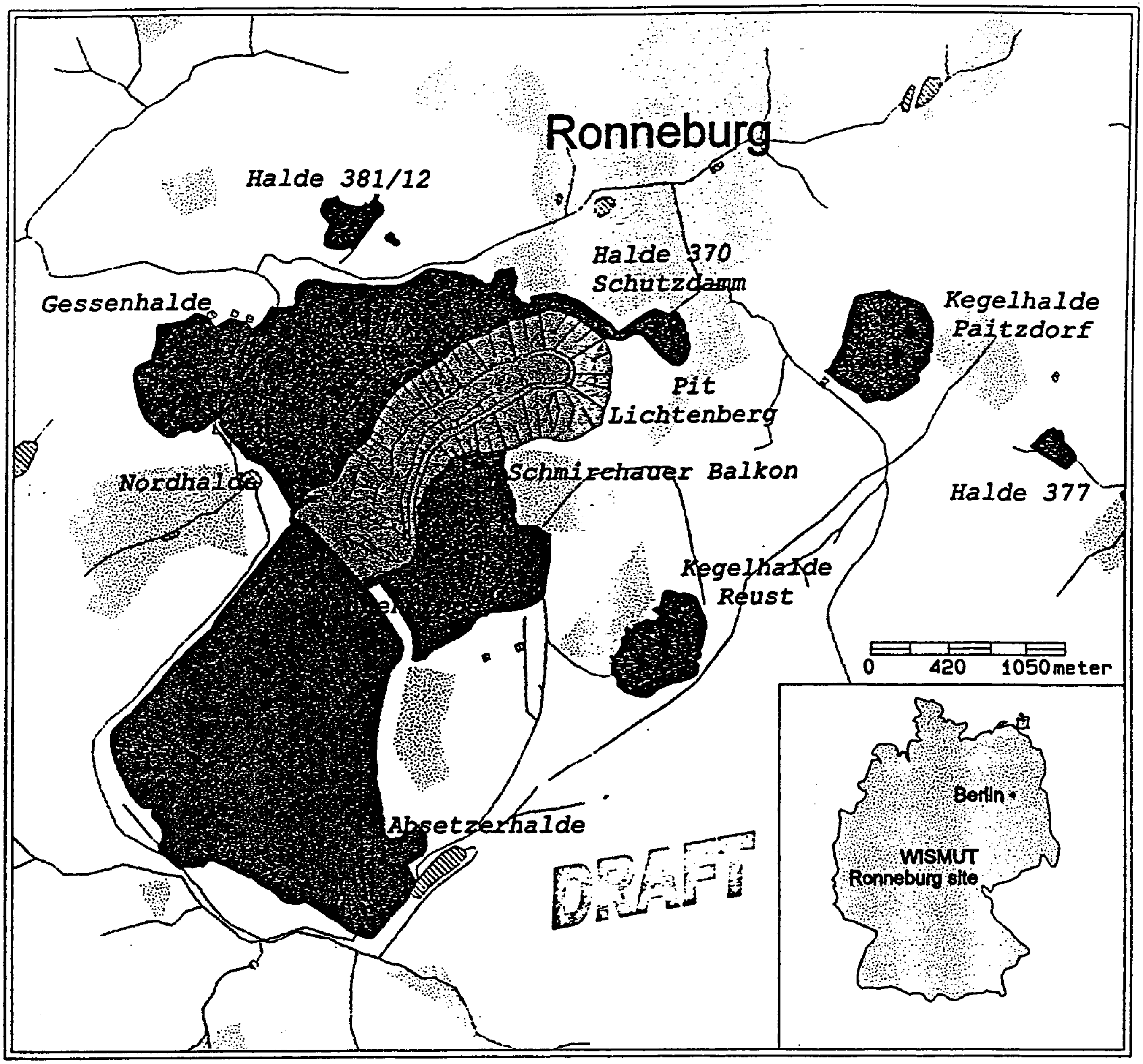

Figure 1 Plan of Ronneburg Mining District

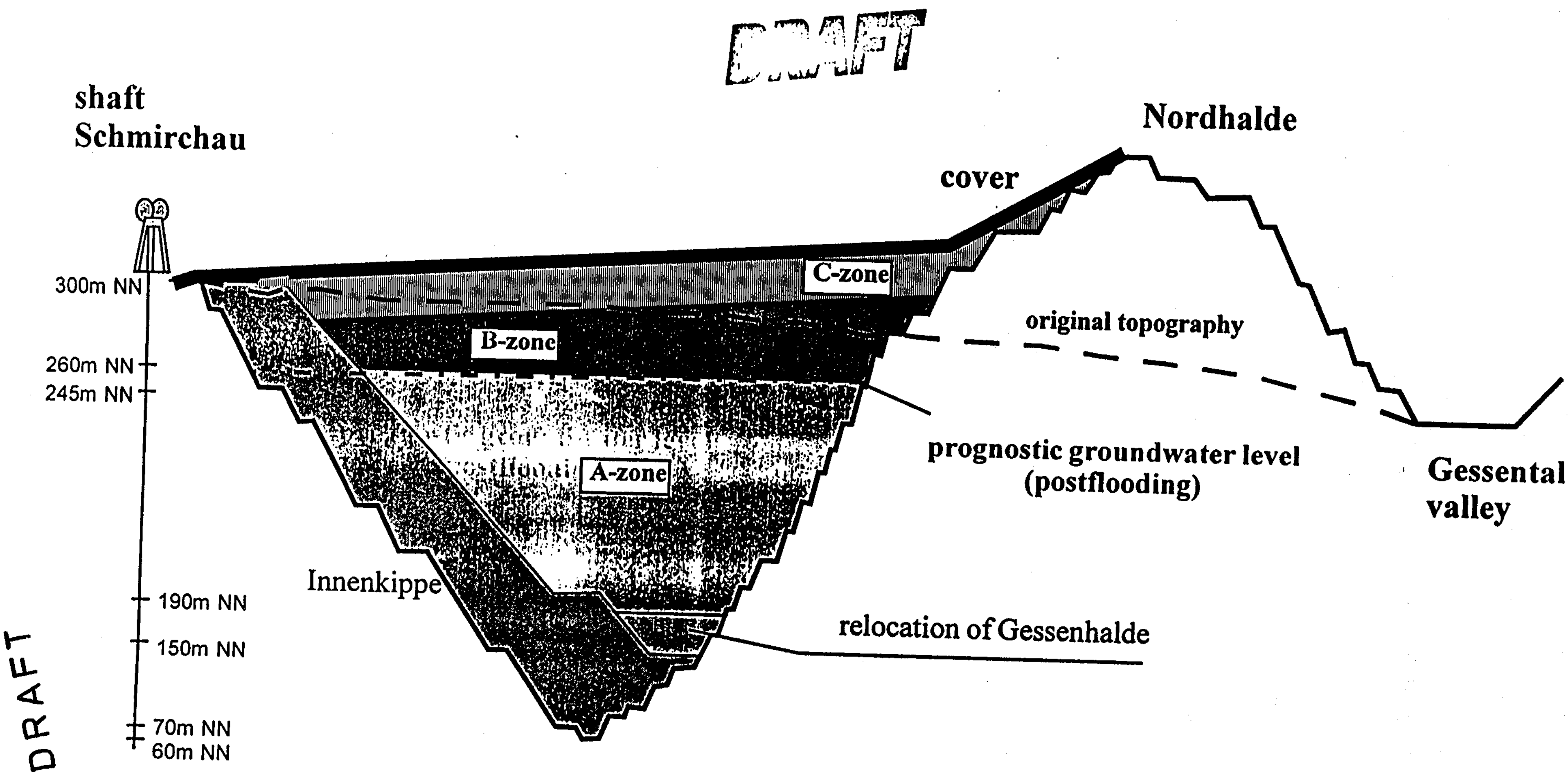

Figure 2 Section through Lichtenberg Pit showing waste rock relocation Zones A, B and C

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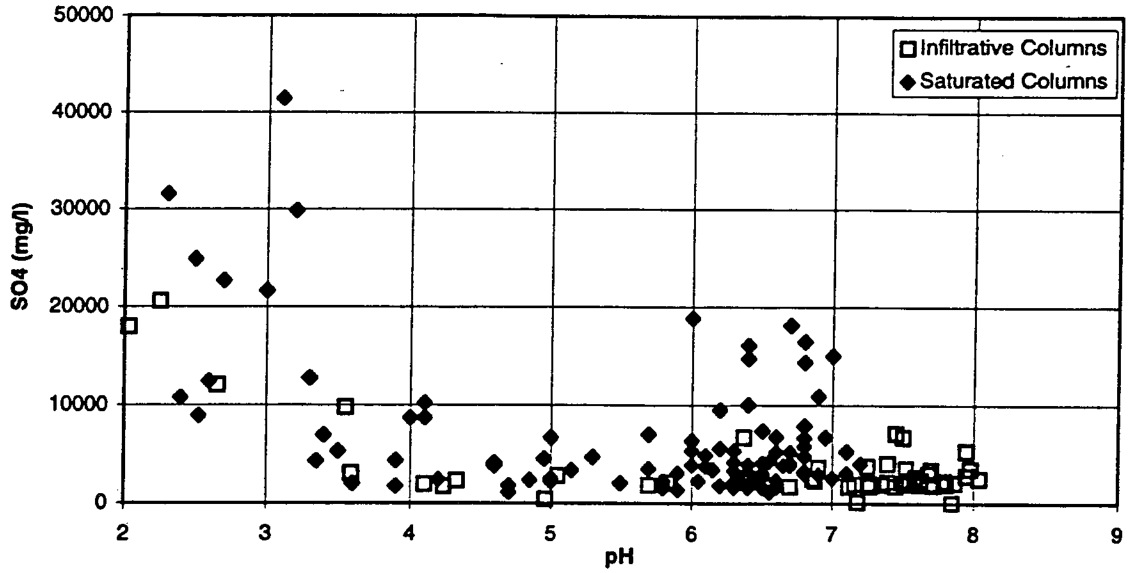

Figure 3. Column test results - sulphate vs. pH

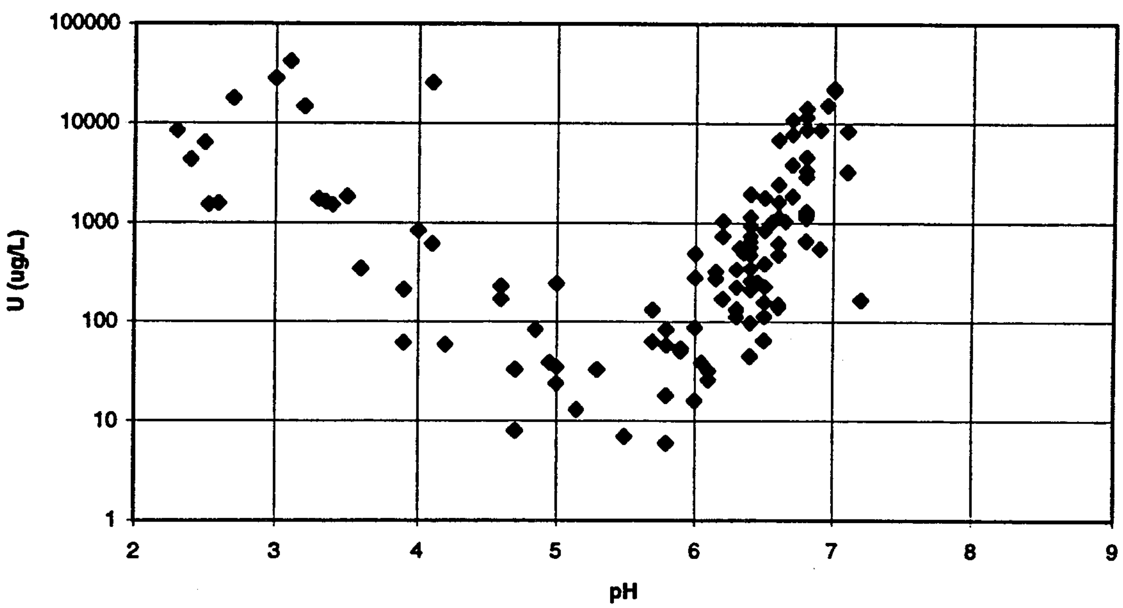

Figure 4. Saturated column test results - uranium concentrations vs. pH

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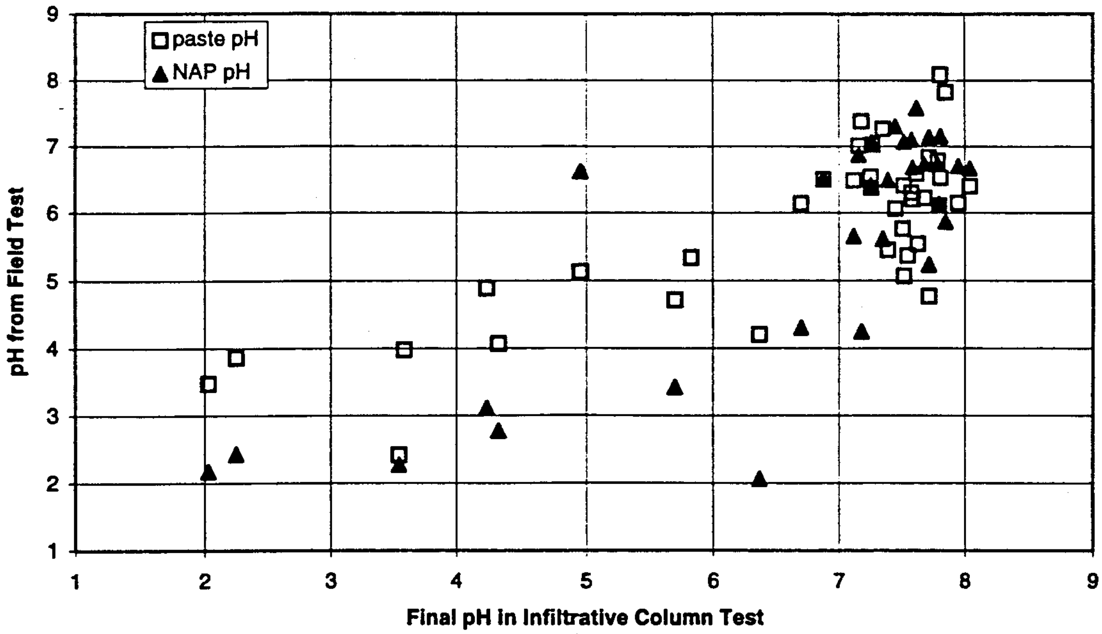

Figure 5. Comparison of paste pH and NAP pH (field tests) with pH measured in column tests

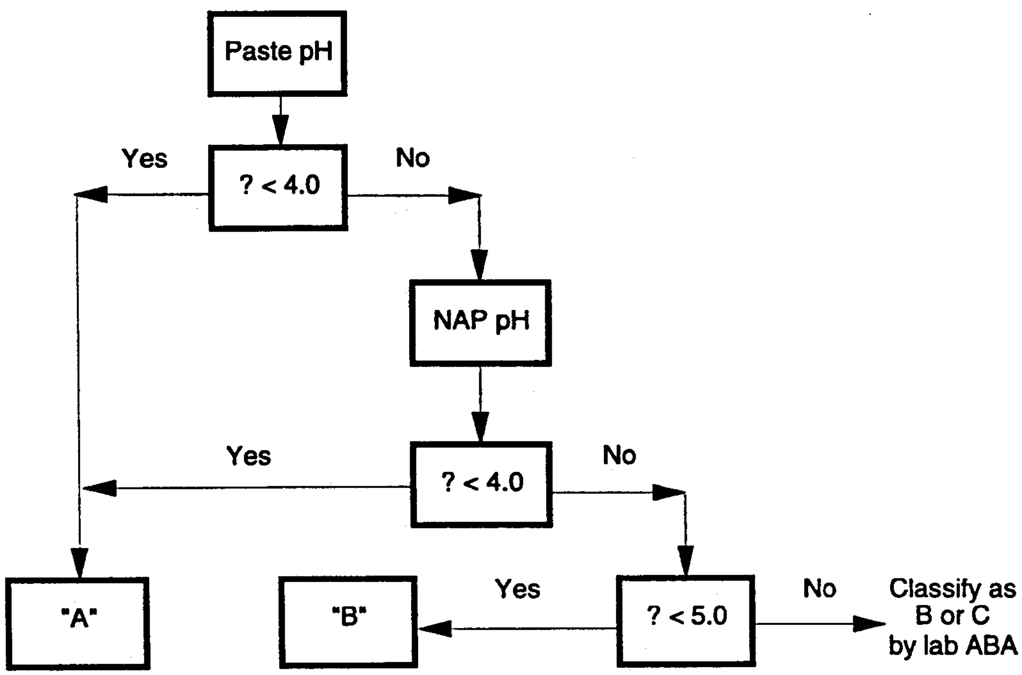

Figure 6. Protocol for using paste pH and NAP pH to classify Absetzerhalde waste rock

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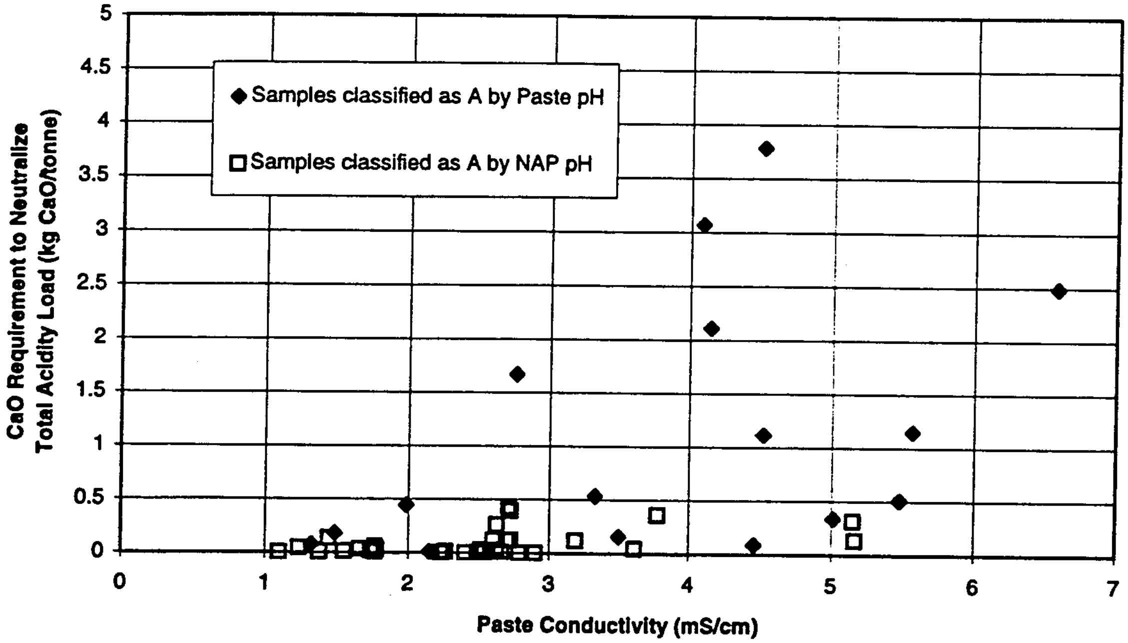

Figure 7. Lime requirements vs. paste conductivity for paste A and NAP A samples. (Lime requirement calculated from total acidity load in saturated column test)

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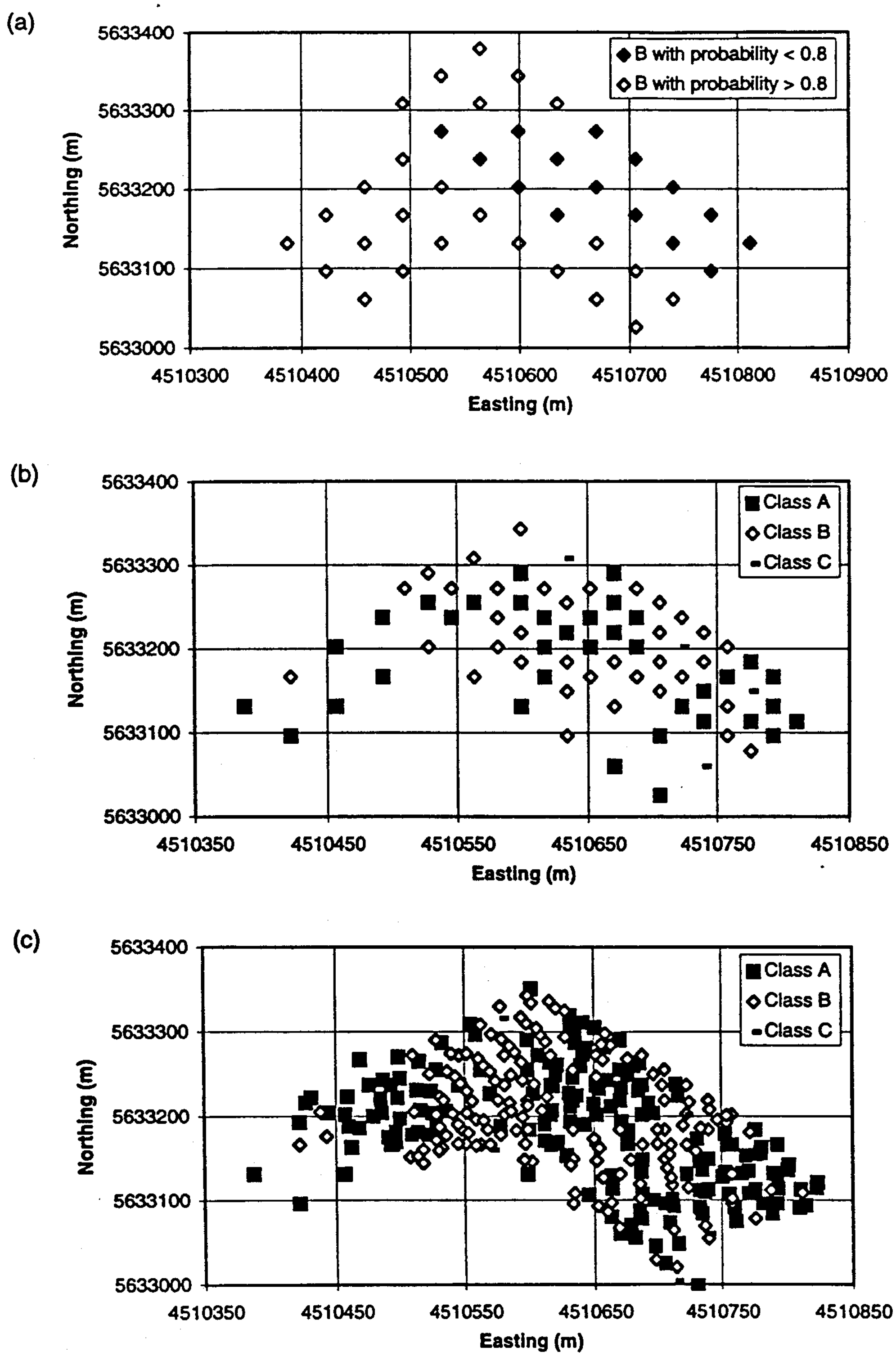

Figure 8. Results from field tests of relocation program:
(a) Kriging results show segment is all Class B
(b) Test pit samples reveal significant areas of Class A material
(c) Face samples confirm presence of Class A material