SELECTED CHEMICAL CHARACTERIZATION OF FIVE MINESOIL PROFILES IN AUSTRALIA. IMPLICATIONS FOR FUTURE LAND USE [1]

by

J.T. Ammons, R.R.P. Noble, J.L. Branson, and D.S Walker [2]

Abstract. Four minesoil profiles were sampled in Queensland and one in New South Wales, Australia, for chemical characterization. These sites represent minesoils from the upper and lower portions of the Bowen Basin, with overburden dominated by Permian sandstone and some mudstones. The objective of this study was to compare chemical properties to establish future land use potential. Total dissolution analysis using a modified micro-wave technique included the following elements: Ca, Cu, Fe, K, Mg, Mn, Mo, Na, P, and Zn. Total C, N, and S were determined using 60 mesh samples on the LECO CNS 2000. In addition, organic C was determined using the Walkely-Black technique. Total P values were low in the Queensland minesoils. Organic C and total N values were higher in the New South Wales minesoil than those values found in the Queensland minesoils. This is primarily due to age of the minesoils. Sodium concentrations are high and may present special problems for plant establishment. Chemical measurements are a key component to assess future land use.

Additional Key Words: minesoil, total analysis, Australia, Permian coal.

Introduction

Minesoil investigations have encompassed a variety of techniques and philosophies world-wide. Many of the investigations are driven by a specific environmental impact such as acid mine drainage and severe soil erosion. These types of episodic events draw attention to the problem, but not to the total evaluation of the minesoil as a resource. Field and laboratory techniques have been established to determine, in advance, potential acidity or basicity of overburden materials for successful, post-mining land uses (Smith et al., 1974), but investigations often focus on a specific problem while some other important properties are ignored.

Minesoils have unique properties that are not fully understood. Research has revealed many of these unique properties, such as contrasting materials spoiled together, that create mottling not specific to redoximorphic conditions. The presence of bridging voids occur at random in minesoil profiles. Some are filled with fine earth materials and others with air. Variability of organic carbon by depth is due to carbon fragments from coal or mixed and redeposited surface materials. An unlimited rooting depth, which is due to the placement of spoil, is one of the properties distinctive to uncompacted minesoils (Ammons and Sencindiver, 1990).

How are some of these unique properties related to future land use? Contrasting materials excavated from different parts of the geologic section during the mining process assure ongoing chemical weathering activity. The weathering activity will, in turn, release plant available nutrients over time since final placement ("auto-fertilization") will reinforce sustainability of vegetation. Bridging voids are created by random packing of soil and rock materials during the deposition of spoil piles. These voids control moisture relationships within the minesoil profile and they may serve as pools or "zones" for plant available moisture. Bridging voids control moisture relationships within the minesoil profile and they may serve as pools or "zones" for plant available moisture. If voids are interconnected, the minesoil may drain freely and become susceptible to drought. Unlimited root penetration is present in most minesoils where compaction has not been a major factor in reclamation efforts. No solid lithic or para-lithic contact is normally present near the surface which allows a larger soil mass for root growth. Root penetration can be confirmed to depths of three meters or more in minesoils with favorable chemical properties (Ammons, 1979).

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[2] J.T. Ammons is a Professor, R.R.P. Noble is an undergraduate laboratory technician, J. L. Branson is a post-doctorial research associate, and D. S. Walker is a research associate, Department of Plant and Soil Sciences, The University of Tennessee, P.O. Box 1071, Knoxville, TN 37901-1071

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These unique physical and chemical properties set minesoils apart from studies of native or undisturbed soil. For this reason, these soils should be described, studied, mapped by depth and eventually placed in a classification scheme for future land use planning.

Large-scale reclamation efforts are underway in the Bowen Basin in Australia. Climate differences within the basin determine the types of rehabilitation techniques to be used. In Queensland, the climate is generally warmer and drier than in New South Wales, which dictates reclamation approaches. Garrahy et al. (1999) reported on perspectives on issues facing the Queensland coal industry that site-specific methodology should be developed for large-scale mined lands. Climate and physio-chemical characteristics of the minesoil should be considered to reach a designated post-mining land use with native "bush land" populated with native plant species.

This paper does not address minesoil classification or measurements of physical properties, but looks at selected chemical properties of five minesoils. The objective of this study was to compare five minesoil profiles for selected chemical properties and discuss the implications for future land use potential.

Materials and Methods

Four minesoil profiles in Queensland, Australia, and one minesoil profile in New South Wales, Australia were sampled for chemical analysis (Fig.1). Elevation, temperature, and mean annual soil temperature were similar at both sites. Near the Queensland site, the elevation is 179m, the mean daily maximum temperature is 29.5°C, and the rainfall is 639.5 mm/yr. At the New South Wales site, the elevation is 216m, the mean daily maximum temperature is 23.8°C, and the rainfall is 652.4 mm/yr. The authors feel the comparisons between these minesoils are valid because the climate is similar and the minesoils originate from rocks of the same geological unit. These minesoils were the result of open cut surface mining of Permian coal in the Upper and Lower portions of the Bowen Basin. The sampling locations in Queensland were at the Oaky Creek Mine and in New South Wales, the Lidell Mine. Overburden rocks were dominantly Permian sandstone with some mudstone and shale (Fig. 2). The minesoil landscape in Queensland was approximately twelve years old with sparse vegetative cover, while the landscape in New South Wales was forty-five years old and covered with mixed grasses.

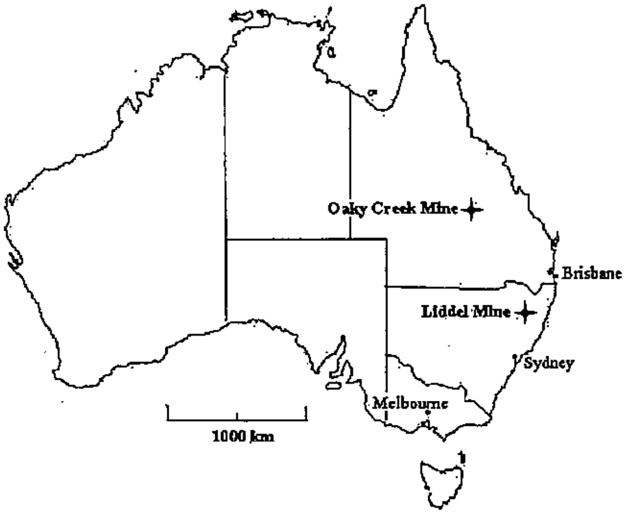

Figure 1. General location of the Oaky Creek and Liddel minesoil profiles

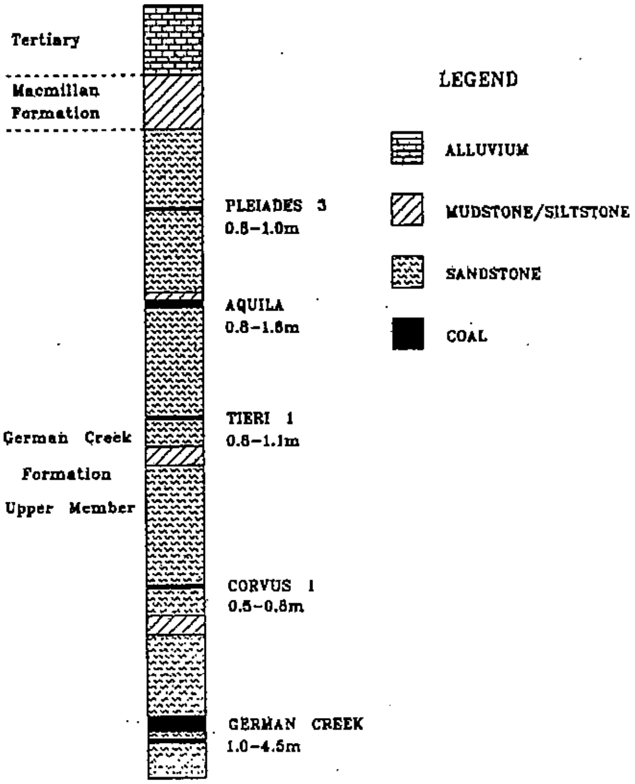

Figure 2. Generalized geologic cross-section of the overburden at the Oaky Creek Mine.

All soil profiles were excavated on steep side slopes (>30 per cent) on cast overburden and then described and sampled according to the Soil Survey Manual (Soil Survey Staff, 1993).

Additional field notes unique to minesoils were recorded (bridging voids and coarse fragments). Samples were mixed, sub-sampled, and crushed to 2mm and 60 mesh for chemical analysis. Total dissolution analysis using a modified micro-wave technique (Ammons et, al., 1995) includes the following elements: Ca, Cu, Fe, K, Mg, Mn, Na, P, and Zn Total C, N, and S were determined using solid samples on the LECO CNS 2000. In addition, organic carbon was determined using the Walkely-Black technique (Jackson, 1958).

Results and Discussion

All of the minesoil profiles in this study were dominated by sandstone rocks. Mudstone and shale were present in small quantities. Minesoil landscapes were created by cast overburden using a dragline creating a "crest and trough" minesoil landscape. Figure 2 is a representative geologic section for the Queensland Oaky Creek mine site, but is also similar to the overburden in New South Wales Liddel mine location.

Chemical properties for all soil profiles by depth are reported in Tables 1 and 2. Selected macro and micro soil nutrient elements were the focus of the analysis. In addition, Na was included because it was found in high concentrations and may influence plant adaptation.

Total P concentrations were extremely low for the minesoils sampled. This element coupled with low total N concentrations typical for most minesoils will inhibit sustainable revegetation. Potassium, Mg, and Ca are present in quantities to sustain long-term vegetation if coupled with a balance of N and P. The micronutrients are present in sufficient quantities for plant growth. Sodium concentrations are high on these minesoils. Ammons et, al. (1999) reported exchangeable Na percentages at levels that would imply a Sodic subgroup for soil classification purposes of these Queensland minesoils.

Table 1. pH, organic carbon, total carbon, total nitrogen, and total sulfur of five minesoils in Australia.

Site	Horizon	Depth (cm)	pH $(1:1H_2O)$	% Organic C	% Total C	% Total N	% Total S
Oaky Creek Mine Pit 1	C1	15	7.2	1.15	1.65	0.07	0.29
	C2	31	7.2	1.07	1.59	0.07	0.26
	C3	53	7.1	1.15	1.61	0.07	0.27
	C4	90	7.1	0.61	1.55	0.07	0.22
	C5	117	7.0	0.53	1.56	0.07	0.35
	C6	150+	7.0	0.76	1.49	0.06	0.60
Oaky Creek Mine Pit 2	A	8	8.0	0.46	1.54	0.06	0.11
	C1	49	8.0	0.99	2.78	0.09	0.33
	C2	86	8.6	1.07	2.34	0.08	0.23
	C3	107	8.7	0.76	2.83	0.09	0.31
	C4	150+	7.5	0.92	2.11	0.09	1.62
Oaky Creek Mine Pit 3	A	12	8.4	1.45	2.96	0.10	0.13
	C1	43	8.3	2.06	4.89	0.15	0.14
	C2	96	8.1	1.83	3.43	0.10	0.04
	C3	150+	8.8	1.76	3.17	0.10	0.04
Oaky Creek Mine Pit 4	A	12	8.0	0.91	2.32	0.11	0.14
	C1	50	8.8	0.76	2.37	0.11	0.17
	C2	100	8.4	1.07	2.27	0.10	0.20
	C3	150+	7.8	0.46	1.36	0.07	0.31
Liddel Mine Pit 1	Ap	10	6.2	9.16	10.93	0.58	0.03
	C1	44	6.7	12.73	13.60	0.55	0.03
	C2	98	7.5	2.55	0.90	0.05	0.00
	C3	150+	8.0	0.60	0.79	0.04	0.00

Table 2. Total dissolution analysis of selected elements in five minesoil profiles in Australia.

Site	Horizon	Depth (cm)	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	Zn
			mg kg^{-1}									
Oaky Creek Mine - Pit 1	C1	15	2758	10	22455	14055	4419	284	5	5305	151	55
	C2	31	2741	10	21310	10390	4169	317	<5	4562	100	59
	C3	53	2899	10	22885	12265	4359	337	6	4756	89	66
	C4	90	3266	12	21755	12605	4730	336	<5	4772	133	56
	C5	117	3120	10	22760	10050	4603	313	<5	5205	162	106
	C6	150+	2979	10	23850	11415	4384	278	<5	5280	114	60
Oaky Creek Mine - Pit 2	A	8	2724	12	21880	17800	4304	278	6	4703	193	68
	C1	49	2001	13	26350	12350	4282	330	<5	3574	125	72
	C2	86	3438	10	20325	15760	4514	301	7	4434	174	59
	C3	107	2014	14	21875	12180	3941	287	6	3138	93	77
	C4	150+	1363	7	37575	14650	3229	202	<5	4400	70	50
Oaky Creek Mine - Pit 3	A	12	2722	12	22385	13545	4712	279	<5	3814	123	50
	C1	43	4294	15	27405	13800	5400	414	<5	3719	109	66
	C2	96	9015	12	23330	10220	7855	493	7	5200	213	59
	C3	150+	6065	14	28365	13885	7470	452	5	5205	161	67
Oaky Creek Mine - Pit 4	A	12	4460	12	16485	13800	4070	204	<5	6770	321	54
	C1	50	4995	12	19565	15075	4617	247	5	5980	344	52
	C2	100	3348	15	24220	11415	3944	270	<5	5485	192	64
	C3	150+	1989	10	20030	15520	3764	168	<5	4691	184	41
Liddel Mine - Pit 1	Ap	10	7025	17	16535	8520	5140	260	8	5260	362	59
	C1	44	11265	22	17000	5705	8335	250	6	4394	477	47
	C2	98	7805	17	24895	9030	6930	257	8	8890	313	79
	C3	150+	8545	24	27540	8175	7760	499	<5	10065	274	65

Age is the Difference

Thomas and Jansen (1985) studied minesoils ranging in age from five to sixty-four years. They concluded surface soil increased in depth and structure based on the increasing age of the minesoil. Figure 3 is a comparison between the four Oaky Creek minesoils (12 years old) and the Liddel minesoil (45 years old). Organic carbon and total nitrogen percentages were much higher in the older minesoil. Time with sustained vegetative cover enhances the accumulation of total N and organic C. With the similarities in climate, organic C seems to be sequestered through time in the older minesoil.

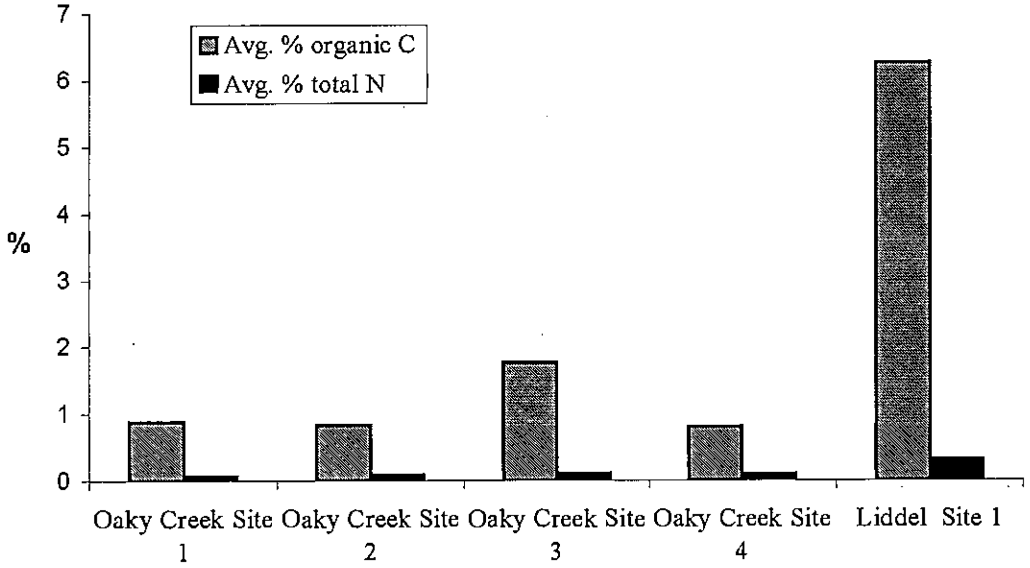

Figure 3. Comparison of organic C and total N of five Australian minesoils.

Conclusions

In the study of these five minesoils, the following conclusions are presented.

1. Phosphorus will have to be included as a treatment to obtain long-term sustainable vegetation. A selection of low P tolerant native plants may reduce the P requirement for reclamation purposes.

2. Nitrogen will have to be added until a sustainable grass and legume cover can be established.

3. Sodium concentrations study with special attention to plant adaption.

4. Most micronutrients are adequate for sustainable vegetation.

5.Time and patience is a factor. Once adequate land treatment is initiated, time and maintenance are critical for establishment of sustainable vegetation.

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