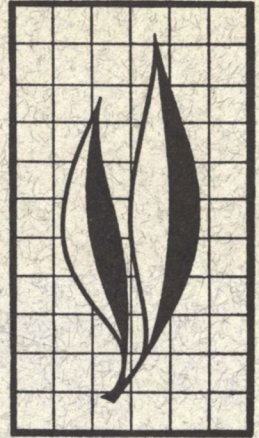# Characteristics of High Boron Soils in Western Kern County

F. T. Bingham, R. J. Arkley, N. T. Coleman, and G. R. Bradford

Ten soil profiles were selected from the major soil bodies under development for irrigated agriculture in Western Kern County for examination of properties and soil-forming processes in relation to crop capability and pretreatment needs. The soils were carefully examined in the field and sampled by genetic horizons for detailed examination of chemical-mineralogy properties. Unusually high amounts of salinity, alkali, and boron were found in subsurface horizons of practically all soils. Saturation extracts of some soils contained also unusually large concentrations of copper, iron, molybdenum, zinc, lithium, and selenium. The clays were found to be almost exclusively montmorillonitic. All soils contained lime and gypsum.

Boron sorption-desorption characteristics were associated with hydroxy iron compounds rather than with aluminum. The relation between sorbed and soluble boron was adequately described mathematically with a Langmuir isotherm equation.

THE AUTHORS:

F. T. Bingham is Professor of Soil Science, Department of Soils and Plant Nutrition, Riverside

R. J. Arkley is Instructor and Soil Morphologist, Department of Soils and Plant Nutrition, Berkeley

N. T. Coleman is Professor of Soil Science, Department of Soils and Plant Nutrition, Riverside

G. R. Bradford is Specialist, Department of Soils and Plant Nutrition, Riverside

*F. T. Bingham, R. J. Arkley, N. T. Coleman,
and G. R. Bradford*

Characteristics of High Boron Soils in Western Kern County[1]

INTRODUCTION

A MAJOR EXPANSION of irrigated agriculture is taking place in the southwestern part of the San Joaquin Valley with the completion of the California aqueduct along the westside of the Valley. Present projections encompass approximately 200,000 acres of arid range land in Western Kern County for development and irrigation over the next few years. During the first year of water service, more than 45,000 acres of land were developed, and 18 different crops were produced (Committee, 1968a, 1968b). In 1969, the area under irrigation was estimated to exceed 70,000 acres. Shortly, lands north of Kern County, in Kings and Fresno counties, along the westside of the Valley, will likewise come under irrigation, bringing the total to more than 600,000 acres. Virtually all of the lands will be under sprinkler irrigation management.

Crop selections are based on the need to offset high water costs, and hence will consist of high-income-yielding crops, such as citrus, deciduous fruits, and certain vegetable and field crops. The climate, in general, is favorable to a wide selection of crops under irrigation management. However, recent disclosure of salt-affected soils in the area (Committee, 1968a, 1968b) introduces the possibility of management problems with tree crops and others sensitive to salts, Na, and B. This information stems from recent reconnaisance surveys of the westside soils and, by the nature of the observations, is not sufficiently detailed to reveal the extent of lands affected, the chemical-mineralogical character of the soils, or overall to serve as a basis for recommending reclamation procedures. Therefore, the authors initiated an investigation to evaluate the nature of salt accumulations, the chemical-mineralogical properties, and the microelement status of principal soils of the westside. The results are relevant to an understanding of the salt-affected soils and provide a basis for planning management practices, including reclamation.

MATERIALS AND METHODS

Description of soils

The soils are on broad, confluent alluvial fans sloping gently eastward from the foot of the Coast Range to a flat basin in the trough of the San Joaquin Valley. The fans are fed by small streams that flow only for short periods in winter. Stratified alluvium from calcareous sedimentary rocks of the Coast Range was apparently deposited by flashfloods, and because of the arid climate, remains porous, exhibiting subsidence tendencies.

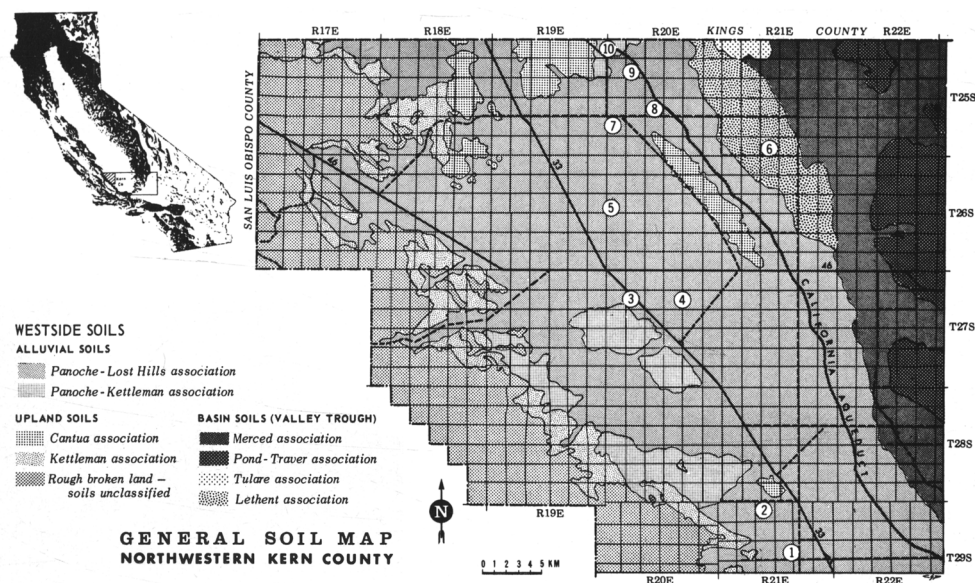[1] Submitted for publication December 29, 1969.

Fig. 1. General soil map of westside area [after Huntington (Committee, 1968a)] with locations of profile sites.

The soils are all yellowish (2.5 Y hues), light-colored (values to 6 or 7 dry, and 4 or 5 moist), and calcareous throughout except for the basin soils which are greyish brown (dry) and dark greyish brown (moist) and have lime only in the subsoil. Gypsum is often present in the lower horizons.

The principal soils under the development west of the aqueduct are classified as alluvials, specifically of the Panoche-Lost Hills series association. The Panoche soils are classified as Xeric Torriorthents, and the Lost Hills soils as Typic Haplargids. The basin rim soils, immediately below the aqueduct, are members of the Lethent or Merced association. Soils of the Lethent series are classified as Typic Natrixeralfs. Additional details on soil series and associations, in relation to topography and proximity to the aqueduct, are given in figure 1.

Soil profile sites

R. J. Arkley's earlier survey of the area (unpublished) enabled the authors to select 10 soil profiles along a 50 mile transect through the westside area for detailed examination (see figure 1 for specific location). The soils were selected because they were representative of large bodies of soil within the area, and also because they exhibit a range of properties including texture, profile development, and B concentration. Table 1 contains a summary of profile locations, soil types, and horizons.

Each profile was examined carefully and sampled by horizons for detailed study in the laboratory.

Laboratory analysis

Forty-five soil samples were air dried, passed through a 2-mm sieve, and examined.

Salinity appraisal was conducted by the saturation extract procedure, developed and described by the staff of the United States Salinity Laboratory (1954). Measurements included moisture content of the saturated paste (Pw_{sp}, percentage), pH of the saturated soil paste (pH_{sp}), electrical conductiv-

TABLE 1

PROFILE LOCATION, SERIES TYPE AND HORIZON, AND SAMPLE NUMBER

Profile number and location	Soil type and horizon	Laboratory sample
		No.
Sect. 14 T 29S R21E	*Panoche clay*	
	0- 30 cm A1	1a
	30- 84 cm IIC1	1b
	84-152 cm IIC2	1c
Sect. 4 T 29S R21E	*Panoche sandy clay loam*	
	0- 76 cm C1	2a
	76-107 cm IIC2	2b
	107-152 cm IIC3	2c
Sect. 8 T 27S R20E	*Panoche loam*	
	0- 36 cm A1	3a
	36- 69 cm C1	3b
	69- 97 cm C2	3c
Sect. 10 T 27S R20E	*Panoche sandy clay loam*	
	0- 33 cm A1	4a
	33- 48 cm C1	4b
	48- 84 cm C2	4c
Sect. 18 T 26S R20E	*Panoche clay loam*	
	0- 46 cm A1	5a
	46- 91 cm C1	5b
	91-137 cm C2	5c
Sect. 33 T 25S R21E	*Lethent clay loam*	
	0- 20 cm A1	6a
	20- 61 cm IIB1	6b
	61-107 cm IIB2t	6c
Sect. 30 T 25S R20E	*Panoche sandy clay loam*	
	0- 23 cm A1	7a
	23- 38 cm C1ca	7b
	38- 66 cm C2ca	7c
Sect. 21 T 25S R20E	*Lost Hills clay loam*	
	0- 25 cm A1	8a
	25- 58 cm B1ca	8b
	58- 86 cm B2tca	8c
Sect. 8 T 25S R20E	*Panoche silty clay*	
	0- 30 cm A1	9a
	30- 61 cm C1	9b
	61- 86 cm C2	9c
Sect. 6 T 25S R20E	*Panoche sandy loam*	
	0- 30 cm C1	10a
	30- 61 cm IIA1	10b
	61- 91 cm IIC1	10c

ity of the saturation paste extract (EC_e), and the common soluble ions including boron. Sodium adsorption ratio of saturation extracts were calculated from soluble Na and Ca + Mg concentrations as me/1 ($SAR = Na \div \sqrt{\dfrac{Ca + Mg}{2}}$). An additional set of saturation extracts were prepared from subsoil samples for spectrographic analysis of various microelements.

The mineralogical composition of the $< 2\mu$ soil fraction was determined by X-ray diffraction, with the use of a Norelco Geiger Counter with Ni-filtered Cu K radiation. The relative contents of montmorillonitic, micaceous, and kaolinitic clays were estimated from X-ray diffraction peak intensities. Alkaline earth carbonates (calculated as $CaCO_3$) were measured manometrically according to the procedure described by Williams (1949). Gypsum was estimated conductometrically from an acetone extraction of soil (Bower and Huss, 1948). Readily reducible Fe was extracted with a dithionite solution, according to the procedure outlined by Kunze (1965). Hydroxy Al was extracted with a sodium citrate solution (Hatcher *et al.*, 1967). Specific surface measurements of whole soils were made by a technique using ethylene glycol monoethyl ether as an adsorbate (Heilman *et al.*, 1965),

Soil B fractions that were measured included total B, sorbed B, soluble B, and dithionite extractable B. Total B was determined by a Na_2CO_3 fusion process. Sorbed B was considered to be the boron removed from soil with five successive water extractions (5 g soil: 25 ml H_2O; 30-minute shaking period). Soluble B was that measured in the saturation extract and presumed to be equal to that of the soil solution. The dithionnite extractable B was that removed with the readily reducible Fe fraction. All values were corrected for amount of B present in the soil solution.

TABLE 2
SATURATION EXTRACT ANALYSIS

Profile sample	Saturation extract analysis							
	pH_{sp}	PW_{sp}	EC_e	Cl	SO_4	NO_3	B	SAR
No.		*per cent*	*mmho/cm*	*me/l*			*mgB/l*	
1a	7.9	40	1.1	2	1	1.9	0.6	1
1b	8.1	32	0.9	3	2	1.1	2.7	4
1c	8.0	38	5.1	10	42	1.1	19.4	6
2a	7.9	22	0.7	2	0.4	0.1	0.4	2
2b	8.3	38	2.2	8	11	0.4	5.1	7
2c	7.9	34	5.6	13	45	1.4	13.6	7
3a	8.0	37	4.6	31	4	0.3	1.8	22
3b	8.1	36	12.7	94	12	5.5	14.0	46
3c	8.1	40	13.8	95	16	7.8	18.0	42
4a	8.0	25	0.5	1	2	0.1	0.3	6
4b	8.1	27	0.7	3	2	0.6	0.3	5
4c	8.2	24	1.2	6	2	0.6	0.4	8
5a	7.8	36	3.1	18	7	0.6	0.5	6
5b	7.8	36	8.4	41	41	4.7	4.6	10
5c	7.9	40	8.2	37	39	9.4	4.2	9
6a	7.5	35	0.7	1	3	0.1	1.0	2
6b	8.2	58	19.0	83	137	0.4	44	42
6c	8.3	60	37.1	167	300	0.4	98	77
7a	8.0	24	1.1	4	3	0.1	0.7	5
7b	8.0	36	3.3	19	8	0.1	1.0	16
7c	8.0	46	6.0	23	27	5.3	6.9	21
8a	7.7	30	1.1	2	1	0.1	0.4	6
8b	7.8	44	5.7	46	6	0.7	4.9	26
8c	7.7	40	13.0	79	54	2.8	12.5	24
9a	7.8	42	0.9	1	4	0.1	0.3	1
9b	7.8	44	2.0	11	8	0.6	1.4	5
9c	7.9	38	2.9	14	14	1.1	2.6	6
10a	7.8	29	0.7	1	1	0.1	0.4	2
10b	8.1	40	1.1	4	1	0.3	1.2	15
10c	8.1	46	4.6	22	8	2.0	6.2	21

RESULTS

Saturation extract appraisal

Table 2 summarizes the saturation extract analysis. To conserve space, only the data for the upper three horizons are reported. The results show that the soils are slightly alkaline, with pH values ranging from 7.7 to 8.3, and all contain salts in the lower horizons. For example, EC_e values extend up to 67 mmho/cm but, in general, the values range between 10 and 20 mmho/cm. As might be expected, the salts are Cl- and SO_4-species, mainly. However, some soils contain unusually large amounts of NO_3 (up to 14 me NO_3/l). According to SAR criteria (U. S. Salinity Laboratory, 1954), seven of the soils have excessive amounts of exchangeable Na (see the Lethent soil, No: 6, in particular).

The microelement data are given in

<div align="center">TABLE 3</div>

<div align="center">MICROELEMENT COMPOSITION OF SATURATION EXTRACT</div>

Profile sample	Microelement concentration							
	Cu	Fe	Li	Mn	Mo	Ni	V	Zn
No.	*mg/l*							
1b..............	0.11	0.11	0.22	<0.03	0.03	0.03	0.03	0.17
2b..............	0.09	0.09	0.20	<0.03	0.03	0.03	0.03	0.11
3b..............	0.09	0.10	0.45	<0.03	0.20	0.02	0.30	0.06
4b..............	0.07	0.04	0.10	<0.02	0.02	0.05	0.06	0.12
5b..............	0.08	0.06	0.24	0.22	0.20	0.02	0.02	0.04
6b..............	0.14	0.13	0.22	<0.01	0.38	0.02	0.07	0.21
7b..............	0.06	0.05	0.17	<0.02	0.02	0.02	0.05	0.03
8b..............	0.06	0.04	0.23	<0.02	0.02	0.05	0.07	0.03
9b..............	0.13	0.10	0.16	0.12	0.01	0.02	0.02	0.23
10b..............	0.08	0.10	0.18	<0.03	0.03	0.03	0.09	0.05

table 3. Although the analysis included many other elements, the data in table 3 show only those present in unusually high concentrations and, as such, might have a bearing on plant and animal nutrition. For example, Mo is extraordinarily high in three soils (Nos. 3, 5, and 6)—0.20 to 0.38 mg Mo/1. Relatively high concentrations of Cu and Zn are present in several soils (Nos. 1, 6, and 9). One soil, No. 3, contains large amounts of V. Likewise, Li concentrations are unusually high in some soils.

Mineralogy

The predominant clay present in the 2μ fraction is montmorillonite (70–85 per cent) with the remainder more or less divided between micaceous and kaolinitic clays (see table 4). Also included are data on surface area, hydroxy Al, and reducible Fe. Measurements of surface area of whole soil vary from 100 to over 300 m²/g, increasing with clay content. Hydroxy Al concentrations are all uniformly low at approximately 0.03 per cent Al, whereas reducible Fe concentrations are considerably greater, ranging from 0.50 to 1.0 per cent.

Boron fractions

Data on total B (fusion analysis), sorbed B, and saturation extract B are also included in table 4. Regarding total B, the analysis reflects wide variations, depending upon the soil and horizon under examination. Low concentrations, for example, fall within the 25 to 30 ppm B range (soils No. 2 and 4). The upper limit extends to 363 ppm B (soil No. 6); however, such an extreme B concentration is definitely not typical for the more recent allivial fan soils. The mean concentration of all surface samples is 49 ppm B. Subsoil samples contain more B.

The sorbed B data also display wide variations, ranging from concentrations of < 10 ppm B for three soils (Nos. 4, 9, 10) to 281 ppm B for the basin-rim soil (No. 6). Sorbed B concentrations increase with depth of profile sampled.

Soluble B concentrations vary widely depending upon soil and horizon (0.1 ppm B to 64 ppm B). As a first approximation, soluble B figures are 20 to 30 per cent of sorbed B. The relationship is more precisely developed, however, by application of the Langmuir adsorption equation. Data from all but soil No. 6 are plotted in figure 2, to illustrate the quantitative relationship between sorbed and soluble B, described by the regression equation $\hat{y} = 0.23 + 0.036X$ ($r = 0.90$). Constants derived from the Langmuir equation for absorption maximum (q) and affinity of reactants (k)

TABLE 4
MINERALOGICAL CHARACTERISTICS

Profile sample	2μ clay*			CaCO₃	CaSO₄ · 2H₂O	Specific surface	Al	Fe	Boron fractions		
	M	Mi	K						Total	Sorbed	Soluble
No.	*per cent*			*per cent*		*m²/g*	*per cent*		*ppm B*		
1a........	70	15	15	3.7	0.03	140	0.038	0.95	68	3.4	0.2
1b........	65	18	27	3.7	0.01	115	0.018	0.80	62	6.6	0.9
1c........	70	15	15	3.6	0.48	128	0.036	0.90	97	29.4	7.8
2a........	70	10	20	3.1	0.02	99	0.034	0.67	27	2.2	0.1
2b........	65	15	20	5.0	0.01	153	0.042	0.83	54	12.7	2.0
2c........	65	10	25	4.0	0.71	129	0.032	0.93	76	21.8	5.2
3a........	85	10	5	7.0	0.01	158	0.018	0.60	52	5.6	0.7
3b........	85	10	5	6.0	0.01	119	0.018	0.50	62	18.4	5.6
3c........	85	10	5	4.0	0.01	110	0.012	0.47	65	22.4	7.6
4a........	60	20	20	2.5	<0.01	87	0.041	0.58	25	1.9	0.1
4b........	65	17	18	4.0	<0.01	102	0.030	0.63	26	2.5	0.1
4c........	65	15	20	2.4	<0.01	95	0.037	0.60	26	1.7	0.1
5a........	90	5	5	4.2	0.01	181	0.018	0.92	65	3.0	0.2
5b........	90	5	5	3.6	0.83	178	0.010	0.98	80	10.4	1.7
5c........	85	7	8	3.1	1.10	175	0.016	1.04	82	10.4	1.7
6a........	70	25	5	0.2	0.01	182	0.052	0.58	68	2.4	0.3
6b........	70	20	10	0.3	1.19	283	0.053	0.53	240	152	25
6c........	75	15	10	0.3	1.10	319	0.051	0.50	363	281	64
7a........	80	12	8	1.3	0.01	162	0.035	0.54	36	3.5	0.2
7b........	85	5	10	7.0	<0.01	167	0.017	0.54	40	4.6	0.4
7c........	80	12	8	8.0	<0.01	218	0.018	0.58	62	18.1	3.2
8a........	85	7	8	2.5	0.01	192	0.032	0.65	48	2.2	0.1
8b........	85	7	8	7.0	<0.01	194	0.018	0.62	60	11.9	2.2
8c........	85	7	8	4.0	0.29	181	0.019	0.67	83	22.3	5.0
9a........	75	10	15	1.1	0.01	226	0.063	1.13	65	3.5	0.1
9b........	74	13	13	1.4	0.01	243	0.055	1.14	77	5.9	0.6
9c........	75	10	15	2.0	0.01	187	0.035	1.02	73	7.0	1.0
10a........	80	15	5	1.4	0.01	131	0.035	0.61	35	1.7	0.1
10b........	85	5	10	3.0	<0.01	222	0.025	0.88	53	3.9	0.8
10c.......	85	5	10	3.0	<0.01	204	0.018	0.81	65	9.9	2.8

* M, Mi, and K represent montmorillonitic, micaceous, and kaolinitic clays.

are, respectively, 28 μg B/g and 0.15 ml/μg B.

Clearly, soil No. 6 is different in many respects from the others. Regarding B, the Langmuir function (y = 0.40 + .0038X; r, 0.004) fails to fit the data with any degree of precision. Hence, figure 2 was prepared exclusive of the data for soil No. 6.

The saturation extract B data (table 2) show low B concentrations, less than 1 mg B/1, for the surface horizon of all soils. The lower horizons of most soils, actually 8 out of 10, contain substantial accumulations of B. Concentrations of 5 to 10 mg B/1 are present in most profiles examined; one profile contains more than 95 mg B/1. A general association exists between salinity (EC$_e$) and soluble B (see figure 3).
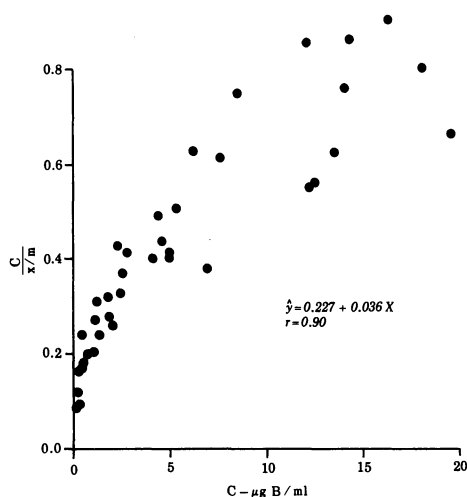
Fig. 2. Relation of B in saturation extract
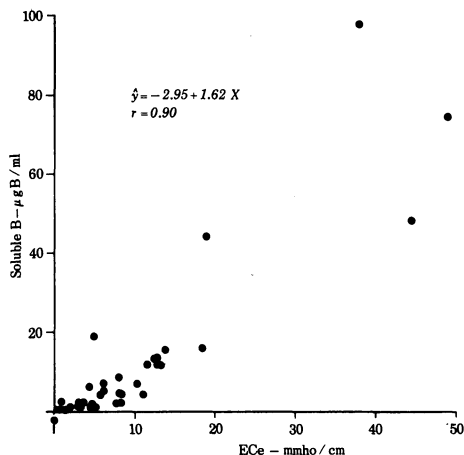to sorbed B, Langmuir plot.

$$\hat{y} = 0.227 + 0.036\,X$$
$$r = 0.90$$

Fig. 3. Relation of EC_e to B in
saturation extract.

$$\hat{y} = -2.95 + 1.62\,X$$
$$r = 0.90$$

DISCUSSION

The relatively widespread occurrence of subsoil salinity, alkali, and boron in Western Kern County indicates that soils along the westside of the San Joaquin Valley and extending into Kings and Fresno counties, may also be affected because similar land forms and geology extend northward into Fresno County. However, a detailed soil survey is needed to evaluate the extent of lands affected with subsoil salinity.

Reclamation of salt-affected lands may be difficult to effect because of the clay composition of the soils. According to studies by McNeil and co-workers (1966a, 1966b, 1968), soils that are predominantly montmorillonitic exhibit markedly reduced drainage characteristics in the presence of relatively low levels of exchangeable Na upon reduction of the electrolyte concentration. The hydraulic conductivity of montmorillonitic soils drops off with increasing exchangeable Na above 8–12 per cent. Field studies should be conducted to evaluate the water transmission properties of the westside soils under a variety of salt and alkali conditions.

Regarding microelements, the following median concentrations taken from G. R. Bradford's unpublished saturation extract analysis of 68 soil survey samples, representing 30 soil series in California, are presented for comparison with the data in table 3: Cu, 0.03 mg/1; Fe, 0.03 mg/1; Li, 0.05 mg/1; Mn, < 0.01 mg/1; Mo, < 0.01 mg/1; Ni, < 0.01; V, 0.01 mg/1; and Zn, 0.04 mg/1. In view of the range of analysis we noted for the westside soils compared with Bradford's median values, several questions concerning management of the soils arise.

One question relates to Mo toxicity or molybdenosis with respect to cattle. Several of the westside soils contain unusually high concentrations of Mo compared with the median values listed, or compared with values found among soils exhibiting toxic Mo characteristics in Fresno County. The Mo content of the saturation extract of these soils in Fresno County ranged from 0.01 to 0.10 ppm, with a median concentration of 0.04. The Mo content of the Lethent soil (No. 6b) is approximately tenfold

greater than the median level for soils known to possess toxic levels. Forage material and particularly legumes, such as alfalfa, grown in these newly developed areas with high Mo soils would be expected to accumulate excessive levels of Mo, posing a hazard if fed to livestock (Barshad, 1948, 1951; Dick, 1956).

The V analyses are interesting, too, in that the amount of V is relatively high in the westside soils compared with the 68 soil survey samples. Although information is limited on the effects of increasing V in the soil solution, it suggests some significant interactions. Catalina (1966) reported an enhancement of nitrate absorption by plants in sand-culture following the addition of V. According to Cannon (1963), small amounts of V are stimulating to plants, whereas greater concentrations (10–20 mg/1) are harmful, except to legumes.

Geochemical associations discussed by Cannon (1963) suggest the possibility of high Se in the westside soils. The Se content of profile samples 3b, 6b, and 9b was found to be less than 0.02 mg Se/kg when the HBr distillation technique described by Robinson et al. (1934) was used. Less than 0.1 mg Se/kg is considered low and 1.0 mg Se/kg is high (Ganje, 1966). However, the low Se content found in these three samples does not preclude the possibility of a higher and possibly toxic level of Se in adjacent areas. For example, local cattlemen report that soils to the immediate south, in the Maricopa district, contain sufficient Se to produce toxic forage.

The Li values are also unusually high, suggesting possible toxicity to sensitive crops which, generally, are those also sensitive to Na (Bingham,, et al., 1964).

The Cu, Fe, Mn, Ni, and Zn results are of interest because the concentrations of these elements in the saturation extracts are relatively high, raising questions concerning their source, solubility, and biological significance; these unknowns might be resolved by specific studies.

The unusually large accumulation of NO_3 is surprising, in view of the fact that westside soils have never been cultivated or fertilized. However, similar observations were made in salt-affected soils in Colorado, Utah, and Washington (Stewart and Peterson, 1917; Kelley, 1951; U. S. Salinity Laboratory, 1954). Kelley (1951) discussed the origin of "nitre" soils in his book on alkali soils. Stewart and Peterson (1917) suggested that "nitre soils" were frequently associated with neighboring sedimentary rock formations containing nitrates. The NO_3, accumulating in westside soils, likewise could have been derived from the parent rock and alluvium eroded from the shale and sandstone formations of the Coast Range. Ground waters, enriched with NO_3, also could be a contributing agent. As for management considerations, the NO_3 will readily leach out of the profile once irrigation is started, but its subsequent contribution to drainage waters and ground water supplies may become a matter of concern.

The excellent agreement between saturation extract B and sorbed B, reflected in the Langmuir isotherm plot (figure 2), indicates that the alluvial soils have similar absorbent activity. Recent studies of the B sorption-desorption process in soils suggest that the active components consist of Fe and Al hydroxy compounds in combination with a surface parameter (Hatcher and Bower, 1958; Hatcher et al., 1967; Hingston, 1964; Sims and Bingham, 1967a, 1967b, 1967c). Extremely small amounts of Al were extracted from the westside soils, indicating that the sorption activity is related more to the hydroxy Fe component. The observation that relatively large amounts of Fe only, are extracted (0.5 to 1.0 per cent) supports the view that Fe rather than Al compounds are responsible; and the relationship between dithionite extractable B and sorbed B (figure 4) provides further confirmation.
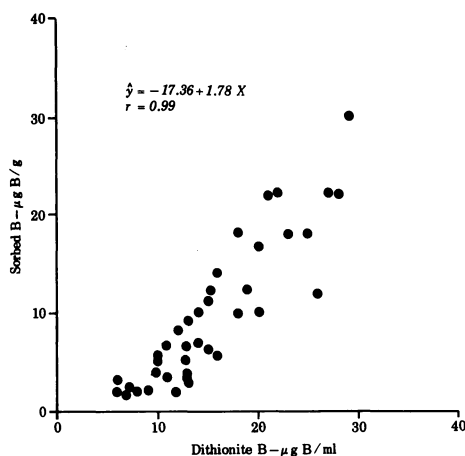
Fig. 4. Relation of B extracted with dithionite solution to sorbed B.

As to plants, the saturation extract B is usually taken as a measure of available B (Hatcher *et al.*, 1959). For example, concentrations of 1 ppm B, 5 ppm B, and 10 ppm B are used by many California agronomists as threshold concentrations indicating a B hazard, respectively, for sensitive, semitolerant, and tolerant crops. Hence, much of the westside development, if it is planned for tree crops, should include reclamation as a pretreatment before planting deep-rooted, B-sensitive plants.

Thus far, relatively little success has been attained in delineating hazardous areas. Soils are often stratified or buried, or exist as overwashed material; they are quite variable. However, several observations have been made regarding soluble B. One is that soils at the lower end of the alluvial fans, and in the valley trough, contain higher B levels than those at the higher positions. Soil No. 6 may be cited. Another obser-

vation is that soils containing excessive amounts of salts usually contain toxic amounts of B (figure 3).

Boron source

The high concentrations of boron, present as total B, are associated with the B content of the parent material. The alluvial soils are formed on alluvium washed down from the Coast Range, composed of marine sediments, which usually contain large amounts of B (Bradford, 1966).

Well and spring waters in the area under discussion reflect generally high B levels, also. Wood and Davis (1960) found that most of the well waters (71 total) contained 2 ppm B or more. Many samples contained, according to the authors, approximately 1 ppm B. Hence the surface and ground water supplies are potential sources of B to the soil. The association of EC_e and B suggests that processes responsible for salt accumulation are also responsible for B.

The mechanism of accumulation is not clearly established, but a reasonable explanation appears to be that both soluble salts and boron were deposited with the alluvium by heavily-laden flashfloods, and additions by smaller, occasional stream flows spreading erratically over the fans. The low rainfall (about 5 inches per year) has been sufficient only to leach the soluble salts and boron from the surface layer and to accumulate in lower horizons. The accumulation of salts and boron by upward movement from a groundwater table seems improbable on the well-drained alluvial fans, but may well account for the very high boron and salinity in the basin-rim soils, such as profile No. 6.

CONCLUSIONS

Site selections for orchards in the westside area should be restricted to the alluvial soils (Panoche-Lost Hills association) above the aqueduct. Although subsoil salinity and excessive B is widespread, the alluvial soils have more favorable irrigation-drainage characteristics than the basin rim soils and, therefore, can probably be reclaimed without excessive costs. Reclamation experiments under way near profile site No. 5, indicate that approximately 15 acre-foot of water is required to remove excessive B from a 5-foot profile and considerably less would be required for reduction of salinity to a level safe for tree crops. Obviously, water costs are significant.

As alternative practices, reclamation might be pursued while tolerant crops are cultivated; when levels are reduced to a point not injurious to tree crops, the orchard could be planted. Also, since the surface horizons are leached, possibly an orchard could be established without first reclaming the soil, relying on sprinkler irrigation management to leach the salts and B below the root zone.

The fundamentals of reclamation for the area are centered upon a boron-iron system, from which B desorbs (leaches) sparingly, moving out of the profile according to the hydraulic conductivity or transmission character of the soil. The soils, in general, have low infiltration rates (approximatley 0.1 inch/hour at site No. 5) which limit leaching. Furthermore, the imported water is a low-salt water which may result in a reduction in hydraulic conductivity. A further complication arises from the predominance of montmorillonite, relatively high Na levels in some soils, and stratification of the profiles. Needed areas of research include evaluation of techniques to improve, or at least maintain, transmission characteristics of soils while they undergo reclamation. Soil manipulation (subsoiling, slip plowing), incorporation of amendments, and treatments to enhance iron solubility, combined with sprinkler irrigation variations, are some of the approaches under consideration.

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