THE OCCURRENCE OF A HIGHLY ALKALINE SOLONETZ SOIL IN SOUTHERN QUEENSLAND

By R. F. ISBELL, M.Sc., Chemical Laboratory, Division of Plant Industry.

SUMMARY.

A highly alkaline solonetz soil occurring around Yelarbon is described.

It is suggested that underground water of a high sodium bicarbonate content associated with a fluctuating water-table is responsible for the highly alkaline nature of the soil.

I. INTRODUCTION.

Recent soil survey work in the southern border areas of Queensland (Isbell 1957) has disclosed the presence of an area of a highly alkaline soil which from its morphological and chemical features is thought to be a typical solonetz. The soil occurs surrounding the township of Yelarbon (200 miles south-west of Brisbane) and occupies an area of 10,000-12,000 acres. It is associated marginally with a smaller area of typical solodized-solonetz soils. Its characteristic properties have resulted in the development of an unusual plant community, the stunted and impoverished nature of which has caused the area to be popularly referred to as the Yelarbon "desert".

Skerman (1948) drew attention to the frequent association of sandalwood (*Eremophila mitchellii*) and bull oak (*Casuarina leuhmannii*) with soils characterised by high amounts of exchangeable sodium and/or magnesium. However, although he referred to such soils as solonetz, more recent studies have indicated that the majority, if not all, are better regarded as typical solodized-solonetz soils.

II. THE ENVIRONMENT OF THE AREA.

(1) Climate.

The area has an average annual rainfall of 25 inches, two-thirds of which falls during the summer months of October to March inclusive. Summer temperatures are hot, with the mean maximum for the months of December, January and February being in the vicinity of 92 deg. F. The mean minimum temperature for July, the coldest month, is 41 deg. F. Frosts are common and frequently severe during the winter months.

(2) Geology.

The area is topographically almost level and no surface rock outcrops, except a low ridge of conglomerate and coarse grits situated marginally to the solonetz soils three miles east-north-east of Yelarbon, are present. Although poorly exposed, the upper section of this deposit is heavily impregnated with limonitic material, while at shallow depths this is replaced by an almost white conglomerate. This occurrence appears to underlie the

Yelarbon "desert", as shallow wells in the township penetrate water-bearing gravels, while to the north of Yelarbon near the desert margin an excavated earth tank has exposed weakly cemented white sandstones and grits which may occasionally display a very weak orange mottling. Soil-boring investigations have also revealed the presence of uncemented sands at relatively shallow depths south-east of Yelarbon.

Sediments similar to this are not known from elsewhere in this southern border region but it is likely that they represent a late Tertiary or Pleistocene deposit. In many features they resemble the Pliocene Glendower Formation (Whitehouse 1940).

(3) Vegetation.

On the solonetz soils and also on some areas of the marginal solodized-solonetz soils an interesting *Melaleuca adnata* (tea-tree)-*Triodia irritans* (spinifex) community is developed. The spinifex does not form a continuous ground cover but occurs as fairly large separate clumps. Much of the area presents a scalded claypan-like appearance due to erosion (apparently mainly by wind) of the surface soil horizons.

The tea-tree is always stunted in habit and may occur singly or in small thickets. Also fairly common are low shrubby stands of sandalwood (*Eremophila mitchellii*), many of which are dead. This general stunted aspect of the

Fig. 1.

View of the Yelarbon "Desert", Showing Vegetation of Spinifex, Bull Oak and Tea-tree (background) Developed on the Highly Alkaline Solonetz Soil.

community is quite characteristic, but isolated tree species do occur. These are mainly bull oak (*Casuarina leuhmannii*), poplar box (*Eucalyptus populnea*) and mallee box (*E. pilligaensis*). Normally there is little ground cover apart from the spinifex, although in areas where the topsoil has not been removed there is a sparse growth of *Chloris divaricata* and *C. truncata*. Where overgrazing has been severe, there may be a dense growth of *Bassia tricuspis* and *Salsoli kali*.

The boundary of this typical "desert" community is not sharp except in the south. Where it merges into the surrounding brigalow (*Acacia harpophylla*) and belah (*Casuarina lepidophloia*) forests there is a narrow marginal zone in which there is very little, if any, spinifex and much less tea-tree but an influx of stunted brigalow and belah.

III. DESCRIPTION OF THE SOILS.

(1) The Solonetz Soil.

As Kelley (1951) has pointed out in his review of alkali soils, the Russian term solonetz has not always been used in exactly the same sense. In his early work on alkali soils Gedroiz (1912) used "solonetz" in the sense of a soil containing excessive exchangeable sodium. However, later both he and other Russian workers referred to solonetz as a leached alkali soil, the sub-horizons of which contained more or less exchangeable sodium and the profile of which showed a certain peculiar morphology while there was an absence, or only low concentration, of salts except at considerable depth.

In more recent years many of the soils which would have earlier been designated solonetz have been called solodized-solonetz, but again there has not always been uniformity of usage, some authors placing the emphasis on pure morphology and others on the chemistry of the soils. Thus in Australia Stephens (1953) placed emphasis almost entirely on morphology, while Hallsworth, Costin and Gibbons (1953) in addition stressed the chemical features. In this present study the diagnostic features of a solonetz soil are taken to be those indicated by Hallsworth *et al.* Thus the solonetz profiles are alkaline throughout, strongly so in the subsoils which contain much exchangeable sodium. The B horizon usually displays well developed columnar structure and may or may not be capped by a bleached A_2 horizon.

In the vicinity of Yelarbon the solonetz soils normally have a fairly thin A_1 horizon (up to 4 inches) but this thickness may be increased locally by accessions of wind-eroded material, especially where spinifex clumps exert a binding effect. In other areas the A_1 horizon may be entirely removed.

Usually it is an almost structureless, rather soft, light greyish-brown loam or clay loam which may occasionally give a faint acid effervescence. An A_2 horizon of similar texture may be present, but if so is only slightly bleached.

The B horizons are fairly sharply defined from the A, but although they are clays in texture their consistence is not as hard and tough as in the solodized-solonetz soils. The brownish B horizons have an extremely low permeability to water, in spite of the fact that they appear slightly vesicular. Even after prolonged steady rainfall there is very little penetration of water below the A horizon. Where the A horizon has been stripped by erosion the exposed B horizon will not support any plant growth.

The B_{21} horizon often displays a coarse prismatic or columnar structure, the columns ranging from 6 to 18 inches in diameter and possessing a gently domed upper surface. The B_{21} merges gradually into the B_{22} horizon, which is massive and rather more friable and contains numerous black fleckings, some of which are possibly organic stainings. The deeper horizons are a brown to greyish-brown friable clay which becomes increasingly sandy with depth. Free carbonate is present in the B horizons and increases with depth, becoming prominent in the form of fairly large nodules. It appears from tests that some of this material is sodium carbonate.

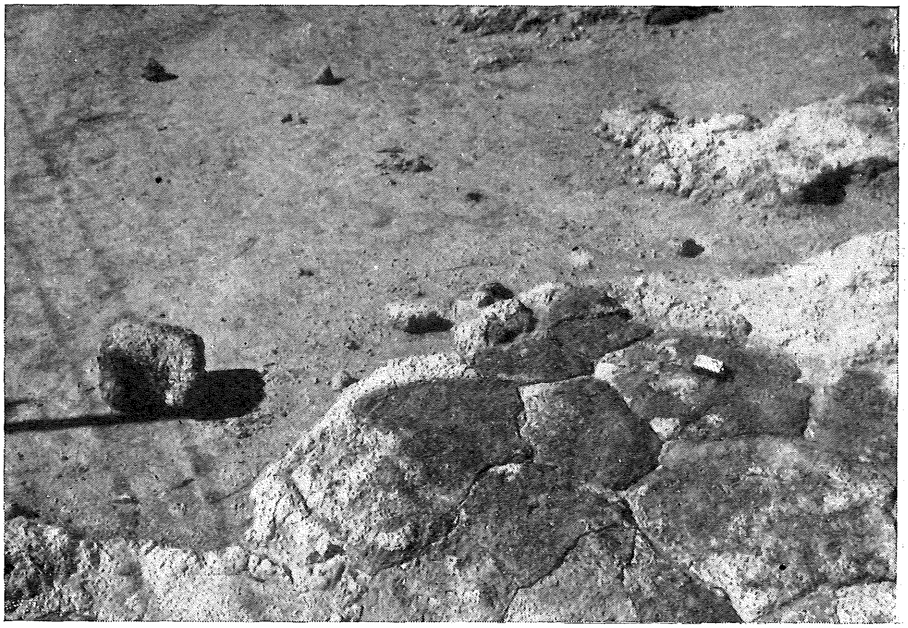

Fig. 2.

The Top of the B Horizon of the Solonetz Soil Exposed by Erosion and Showing the Well Developed Irregular Columnar Structure. The columns are only slightly domed.

The following profiles illustrate the features of the solonetz soils:—

(i.) Profile 3 miles south of Yelarbon along the Keetah road.

A_1	0- 3 in.	Light greyish-brown clay loam, fairly soft and massive, slightly bleached at the base (incipient A_2), fairly sharply defined from
B_{21}	3- 10 in.	Brown medium clay, moderately coarse prismatic structure, hard, merges into
B_{22}	10- 24 in.	Light-brown medium clay, angular blocky to massive, fairly friable, trace of carbonate, merges into
BC	24- 36 in.	Yellowish-brown light clay, friable, slight carbonate.

(ii.) Profile approximately 3 miles south-east of Yelarbon.

A_1	0- 4 in.	Light brownish-grey clay loam, slightly platy on surface then massive and rather vesicular, slightly hard, fairly well defined from
A_2	4- 10 in.	Light-brown clay loam, massive but finely vesicular and fairly hard, not a very sharp break to
B_{21}	10- 18 in.	Brown clay with slight grey mottling and numerous black fleckings. Fairly coarse columnar to prismatic structure with diameter of columns 6-18 in. Still slightly vesicular, hard with a trace of carbonate.
B_{22}	18- 36 in.	Light-brown clay, massive but more friable, some carbonate nodules.
BC	36- 60 in.	Light greyish-brown clay, slightly sandy at depth, fairly friable, with some carbonate nodules.
	60- 72 in.	Pale greyish-brown sandy clay, massive and rather vesicular, with black stainings and some large carbonate nodules but little or no fine earth effervescence.
	72-108 in.	Pale greyish-brown sandy clay loam to loam with some soft carbonate patches.

108-132 in. Light-grey to very pale brownish-grey loamy sand, rather cemented. Mass appears very vesicular but is difficult to wet.

132-162 in. Light-grey to very pale brownish-grey sand, loose and uncemented.

162-192 in. Light-brown slightly coarser sand, loose and soft.

Below 18 in. all horizon boundaries are diffuse and any changes are very gradual.

Analytical Data.

Data for profile (ii.) are shown in Table 1. A particle size analysis shows a moderately high content of fine sand in the A_1 horizon; this is probably partly due to accessions of wind-blown material. A further feature of interest is the rather high silt content throughout the three horizons analysed and the moderately low clay content of the B_{22} horizon.

Table 1.

ANALYTICAL DATA FOR PROFILE (ii).

Lab. No.	1500		1501.		1502.		1503.		1504.	1505.	1506.
Depth (in.)	0–4		4–10		10–18		18–36		36–48	48–60	60–70
Horizon	A_1		A_2		B_{21}		B_{22}		BC	C	C
Texture	CL		CL		C		C		C	C	C(sl.S)
pH	8·1		9·3		10·2		10·2		10·1	10·1	10·1
Free Carbonates (as% CO_2)	..		..		0·7		0·4		..	..	..
Mechanical Analysis(%)	..		..		..		..		..	..	..
Coarse sand	1·7		6·7		..		13·0		..	..	..
Fine sand	34·6		15·4		..		14·3		..	..	..
Silt	37·3		45·7		..		32·1		..	..	..
Clay	17·5		29·7		..		36·8		..	..	..
Moisture	1·6		1·9		..		4·5		..	..	..
Organic Carbon (%)	0·85		0·62		..		..		..	..	..
Nitrogen (%)	0·07		0·03		..		..		..	..	..
Available P_2O_5 (p.p.m.)	32		16		84		264		170	128	114
Chloride as NaCl (%)	0·020		0·043		0·043		0·071		0·070	0·070	0·066
Specific Conductivity (mhos x 10^{-3})	0·09		0·18		0·52		0·80		0·59	0·57	0·55
Exchangeable Cations*	A	B	A	B	A	B	A	B	..	..	..
Calcium	2·7	26	1·5	11	19·0	42	13·8	35	..	..	..
Magnesium	6·0	58	7·5	54	10·2	23	7·3	18	..	..	..
Potassium	0·2	2	0·4	2	0·4	1	0·4	1	..	..	..
Sodium	1·4	14	4·6	33	15·3	34	18·3	46	..	..	..
Total Metal Ions	10·3	100	14·0	100	44·9	100	39·8	100	..	..	..

* A = mg. = equiv./100 g. of soil. B = percentage composition of the exchangeable metal ions.

The A_1 horizon is moderately alkaline, and the remainder of the profile very strongly alkaline (pH 10.0 in the B and lower horizons). Magnesium is the dominant exchangeable metal cation in the A_1 horizon; calcium is subdominant and sodium is also significant. In the A_2, sodium shows a fairly sharp rise and calcium and magnesium remain more or less constant. In the B_2 horizons both calcium and sodium show a very marked increase, with the exchangeable sodium rising to 18 m-equiv. per cent. (46 per cent. of the total exchangeable metal cations) in the B_{22} horizon. Magnesium does not show an appreciable increase in the B horizons and is subordinate to both sodium and calcium. Exchangeable potassium is present in normal amounts throughout. Chloride and total soluble salt contents increase to a maximum in the B_{22} horizon but values are not unduly high (0.07 per cent. NaCl). "Available" phosphate (Kerr and von Stieglitz 1938) is low in the A horizons but shows a very marked increase in the B_2 and lower horizons.

(2) The Solodized-Solonetz Soils.

Marginally in most areas the solonetz soils grade into less alkaline, typical solodized-solonetz types which support a more normal vegetation. These soils have a thin loam or clay loam A_1 horizon (seldom exceeding 4 inches) and usually a bleached A_2 which may be strongly developed. The B horizon is a very tough dense clay or sandy clay which frequently displays columnar or prismatic structure. The following profile from 0.75 miles north of Yelarbon is characteristic:—

A_1	0- 2 in.	Grey loam, compact and slightly hard, merges into
A_2	2- 4 in.	Light-grey sandy clay loam, strongly bleached, massive and fairly hard, sharply defined from
B_{21}	4- 8 in.	Grey-brown heavy clay to sandy clay with light grey mottling. Very hard and tough with some degree of columnar to prismatic structure. Merges into
B_{22}	8- 24 in.	Grey-brown sandy clay, coarse blocky to massive, more friable, merges into
BC	24- 36 in.	Grey-brown clay, slightly gritty with some orange mottling. Friable with free carbonate increasing with depth.

Analytical Data.

The A horizons of these solodized-solonetz soils are slightly acid to neutral and the B horizons are only moderately alkaline (reaching a maximum of pH 8.2 in the B_{22} horizons). The exchangeable metal cations are dominated by magnesium; although sodium is still high it rarely reaches the levels obtained in the solonetz profiles. Chloride and total soluble salt contents are lower in the A horizons than in the solonetz soils, but chloride reaches higher levels in the B_{22} and deeper horizons. "Available" phosphate is very variable but may be very low throughout the profile.

IV. DISCUSSION.

As mentioned earlier, the Yelarbon area is underlain at shallow depths by a series of water-bearing gravel and sand beds. Well records indicate a very marked fluctuation in this perched water-table. After periods of heavy rains it may rise almost to the surface and it is apparently never much deeper than 40 ft. below the surface. Analyses of this water show a high content of sodium bicarbonate (some 12 m-equiv./litre) so that it would appear that this fluctuating water-table affords a most likely explanation for the highly alkaline nature of the solonetz soils. However, there is no evidence to suggest an ultimate origin for the sodium salts; possibly the sediments themselves were inherently salty. Water from the nearby Macintyre Brook is not unduly salty even in dry periods, yet there is some evidence to indicate a relation between the water level in this stream and the height of the perched water-table in the vicinity of Yelarbon.

Possibly the marginal solodized-solonetz soils could represent a stage in the desalinisation of the solonetz soils; some exchangeable sodium has been removed from the exchange complex and soluble salts have been washed further down the profile. On the other hand, field evidence indicates that the solonetz soils are not being leached to any extent under present conditions, so it may be that these marginal soils did not originally contain excessive amounts of sodium salts.

Finally, it may be mentioned that the chemical and physical properties of the solonetz soils prohibit most plant growth. Any possible reclamation is likely to be difficult. Limited experimentation has shown that deep ripping to ensure better water penetration and consequent leaching has effected some improvement, but the presence of the salty water-table at often shallow depths still remains the fundamental cause of the alkalinity problems.

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