SOURCES OF BASE CATIONS IN SOIL SOLIDS AND SOIL WATER: EXAMPLES FROM RED BROWN EARTHS OF SOUTH AUSTRALIA

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INTRODUCTION

Strontium isotope ratios (^{87}Sr/^{86}Sr) have been used extensively as a tracer in a variety of systems including soil weathering (Kennedy *et al.* 1998, Capo *et al.* 1998, Stewart *et al.* 1998), biogeochemical (Aberg *et al.* 1990, Graustein 1998), and groundwater water-rock interactions (Harrington & Herczeg 2003). Their utility is based on Sr being an abundant trace element which is widely occurring and which substitutes in minerals, exchange sites, and biological systems for Ca. The stable isotopes of Sr have very minor mass differences between them and therefore fractionation by physical, chemical and biological processes is minimal. Most importantly for its use as a tracer is the long-lived radioactive decay of ^{87}Rb to ^{87}Sr, which has produced a wide range of strontium ^{87}Sr/^{86}Sr values for different geological materials. ^{87}Sr/^{86}Sr values vary for geologic materials depending on age and initial content of both Rb and Sr. It is thus a very useful tracer for a whole host of settings and systems.

In the study summarised here, Sr isotopic ratios of soil solid, soil carbonate, soil solute extracts, bedrock, silicate-organic dust, carbonate dust, dust extract, irrigation water, and grapes have been analysed in order to better understand the origin and pathways of Sr, and therefore Ca, and by extrapolation the other base cations in the soil-water-plant system. The solid, silicate mineral dominated part of the system is emphasised here and the soil solute, plant (grape) and irrigation water results are presented elsewhere (Green *et al.* 2003). This investigation into the Sr isotope signature of soil solids, associated dust and fine-grained aeolian deposits, and bedrock is an attempt to determine the origin of selected Red Brown Earth soils in South Australia. That is, what component of these soils has weathered from bedrock and what component has accumulated in the soil from atmospheric deposition?

BACKGROUND

The data presented in this summary are from seven soil profiles in three viticulture areas of South Australia: Clare Valley (two profiles); Padthaway (two profiles); and, Coonawarra (three profiles). The Padthaway and Coonawarra sites are in a similar geomorphic context in that they are on the western side of a series of low-relief, north-south trending ridges, part of a well-known sequence of beach-dune ridges and intervening lagoons generated by glacial rise and fall of sea level with concurrent slow but steady tectonic uplift (Sprigg 1952, Cook *et al.* 1977). These low ridges and intervening lowlands are dominated by aeolian geomorphic features; some recently active and some relict from the last glacial age and before. In contrast, the Clare Valley soil site occurs on an uplifted block of basement rock consisting of Adelaide Geosyncline sediments, predominently of the Burra Group. At Clare Valley, the geomorphic context is that of a ridge and valley landscape where resistant units comprise the ridges and less resistant units comprise the valleys. All three sites and seven soil profiles are of Red Brown Earth soils with duplex character (Stace *et al.* 1968).

RESULTS AND DISCUSSION

In general, all soil profiles show strong differences in their Sr isotopic signature between the clayey Bt horizons and the sandy or coarse silt A horizons (Figure 1). The Bt horizons are dominated by Sr isotope signatures that are characteristic of clay minerals. The coarser A horizons are dominated by a signature generated from a minor content of feldspar. The 87/86 strontium ratios of Bt horizons for the Padthaway and Coonawarra profiles cluster in a narrow range of values. The Sr ratios within horizons also remain relatively homogenous down-profile. In the Coonawarra profiles the Bt horizons are over 50 cm thick. Bt horizons in the two Clare profiles, by contrast, vary considerably with depth. In these soils, Sr isotope ratios get higher with depth in the Bt horizons, closer to the value of the local bedrock. ^{87}Sr/^{86}Sr ratios in the A horizons of the Clare profiles get higher closer to the surface, reflecting an increase in feldspar content in the sand and coarse silt fraction as well as a decrease in the clay content.

Of particular interest to the tracing of plants or agricultural products to soils is the difference between soil solids and soil solute extracts (Figure 1). All three sites show similar relationships where soil solute extract signatures are close to seawater composition; the presumed source of most dissolved solutes in the precipitation in these near coastal settings. Also of note is the lack of significant down-profile variation in the soil solute extracts at the scale plotted here. At higher resolution, these soil solute extracts vary with soil

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depth, however, the variation does not correspond to variations in the soil solids (Green *et al.* 2003). Thus, the dominant signal in the soil solute extracts is that of atmospheric inputs with only minor input from soil solids.

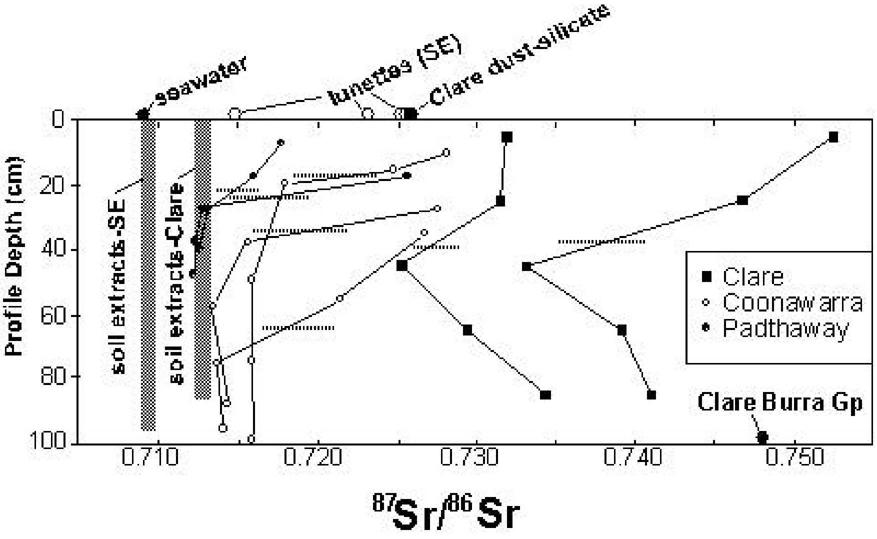

Figure 1: Compilation of Sr isotope data from seven soil profiles from Clare Valley, Padthaway, and Coonawarra areas of South Australia. One profile from the Coonawarra area is from Mee *et al.* (2003). Dashed lines indicate boundaries between the Bt and A horizons.

Dust and fine-grained aeolian samples were also analysed. A modern dust sample was collected from a nearby building roof at the Clare Valley site. For the Padthaway and Coonawarra sites, four samples of fine-grained lunette deposits were analysed from the Bool Lagoon area near Naracoorte. All dust and lunette samples had their carbonate component removed by acidification by a weak acid. Dust from Clare Valley is on the lower end of the Sr isotope values for this site (Figure 1). Lunette samples from the Southeast have a range of values which correspond to the A and B horizons of the soils from this area. The range in values for the lunette deposits likely corresponds to grain-size variations in the deposits with fine-grained clayey deposits having lower ratios.

The Red Brown Earth profiles from the Coonawarra and Padthaway sites are interpreted as the product of fine-grained aeolian deposition, as has been previously interpreted from mass balance geochemistry and Sr isotope ratios (Mee *et al.* 2003). The relatively homogenous Sr values in the Bt horizons of both the Coonawarra and Padthaway soils and similar values from local lunettes support the above interpretation of aeolian deposition from local playa sources. Weathering of this fine-grained material has produced the well-structured and red-brown soils that we see today. The difference in the Sr ratios between the A and B horizons is due to clay minerals dominating the signature of the Bt horizons and feldspar grains dominating the signature of the A horizons (Green *et al.* 2003). These differences in Sr values between the two horizons also argues against the formation of the clayey B horizon from the *in situ* weathering of feldspar grains in the A horizon.

The two Red Brown Earth profiles from the Clare Valley site are interpreted as a mix of *in situ* weathering of underlying bedrock, weathering of bedrock colluvium, and weathering of windblown dust. Based on consistent trends in the two B horizons, these horizons are interpreted as representing a mixing line between windblown silicate dust and bedrock. This geochemistry is supported by field observations of increased occurrence of metasedimentary fragments of bedrock toward the bottom of the profile. Both Clare Valley profiles sit on metasedimentary bedrock at between 80 cm and 100 cm depth. The Sr ratios of the A horizons are, like the soils from the Southeast, strongly influenced by feldspar grains which produce high ratios.

REFERENCES

ABERG G., JACKS G., WICKMAN T. & HAMILTON P.J. 1990. Strontium isotope in trees as an indicator for calcium availability. *Catena* **17**, 1-11.

CAPO R.C., STEWART B.W. & CHADWICK O.A. 1998. Strontium isotopes as a tracers of ecosystem processes:theory and methods. *Geoderma* **82**, 97-225.

COOK P.J., COLWELL J.B., FIRMAN J.B., LINDSAY J.M., SCHWEBEL D.A. & VONDER BORCH

C.C. 1977. The Late Cainozoic sequence of southeast South Australia and Pleistocene sea-level changes. *BMR J. Australian Geophys.* **2**.

GRAUSTEIN W.C. 1988. ^{87}Sr/^{86}Sr ratios measure the sources and flow of strontium in terrestrial ecosystems. *In:* RUNDEL P.W., EHLERINGER J.R. & NAGY K.A. eds. *Stable Isotopes in Ecological Research.* Springer Verlag, New York.

GREEN G.P., BESTLAND & WALKER G.S. in press. Distinguishing sources of base cations in irrigated and natural soils: evidence from strontium isotopes. *Biogeochemistry*.

HARRINGTON G.A., HERCZEG A.L. 2003. The importance of silicate weathering of a sedimentary aquifer in arid Central Australia indicated by very high $^{87/86}$Sr ratios. *Chemical Geology* **199**, 281-292.

KENNEDY M.J., CHADWICK G.A., VITOUSEK P.M., DERRY L.A. & HENDRICKS D.M. 1998. Changing sources of base cations during ecosystem development, Hawaiian Islands. *Geology* **26**, 1015-1018.

MEE A.C., BESTLAND E.A. & SPOONER N.A. in press. Age and origin of Terra Rossa soils in the Coonawarra area of South Australia. *Geomorphology*.

SPRIGG R.C. 1952. The geology of the south-east province, South Australia, with special reference to Quaternary coastline migrations and modern beach developments. *South Australia Geological Survey Bulletin* **54**.

STACE H.C.T., HUBBLE G.D., BREWER R., NORTHCOTE K.H., SLEEMAN J.R., MULCAHY M.J. & HALLSWORTH E.G. 1968. *A Handbook of Australian Soils*. Rellim, Adelaide.

STEWART B.W., CAPO R.C. & CHADWICK O.A. 1998, Quantitative strontium isotope models for weathering, pedogenesis and biogeochemical cycling. *Geoderma* **82**, 173-195.

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