THE ROLE OF SOIL SHRINK-SWELL IN THE FORMATION OF PATTERNED GROUND

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INTRODUCTION

Fowlers Gap is the University of New South Wales Arid Zone Research station and is located 112 km north of Broken Hill on the Silver City High Way. Much of this property is covered by contour-parallel chenopod patterned ground. Most of the work on patterned ground at Fowlers Gap and worldwide has concentrated on water movement and maintenance mechanisms. Shrink-swell has been tentatively suggested as a formation mechanism and a maintenance mechanism; this theory has not been tested.

"Patterned ground" is a term used for an area where a group of micro relief and vegetation features are repeated many times forming a pattern of bare and vegetated bands easily discernible from the air. This phenomenon has been observed in Africa, the Americas, Australia, Asia and Europe (Wakelin-King 1999, Janeau, Mauchamp & Tarin 1999, Wu *et al.* 2000, Tongway *et al.* 2001). At Fowlers Gap the patterned ground is of the chenopod variety with the vegetated zones composed of bladder and pop saltbush (*Atriplex vesicaria* and *Atriplex holocarpa*; Cunningham *et al.* 1981), with stony cover in the bare zones (Macdonald 1999).

Figure 1: the patterned ground near site 1.

This project is assessing the importance of shrink-swell clays as a factor in the formation of patterned ground.

BACKGROUND TO THE PROJECT

Patterned ground was initially recognised in the late 1930s (Menaut & Walker 2001), however, the extent of these formations was not known until aerial surveys following World War II (d'Herbes *et al.* 2001). Dunkerley & Brown (1995) wrote a brief work on the patterned ground at Fowlers Gap in which they offer hypotheses for the origin of the patterned ground. Their explanations take into account both the vegetated and bare ground, but are not tested. However the majority of the work carried out since the extent of patterned ground was first described has concentrated on the vegetated bands or patches. There has only been a small amount of work on surface crusts and overall little work directly characterising the soils in a large-scale survey, or at depth (Wakelin-King 1999). As the patterning is composed of both vegetated and bare areas this study aims to redress this neglect of the bare zones.

The patterned ground of Fowlers Gap is composed of a mixture of chenopod vegetation and stone covered bare zones. Banding at Fowlers Gap is contour parallel, and varies from strongly banded to patched. The patterns change from being isolated clumps of vegetation on the steepest slopes towards thick banding at the base of and lowest gradient section of a slope. There is a distinct lack of surface stones in the vegetated zones (Dunkerley & Brown 1995).

It is agreed by several authors that although these ecosystems seem to be fragile, they are resilient in the face of climate change and moderate grazing. The pattern around Broken Hill has been maintained through

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drought and 150 years of grazing including periods of over stocking (Dunkerley & Brown 1999, Mabbutt 1978).

There is also agreement about the major influential factors, mean annual rainfall and gradient of slope, with patterning only forming on gentle slopes with semiarid to arid rainfall (Valentin *et al*. 1999).

As Dunkerley & Brown (1999) point out, the soil properties, including shrink-swell, of patterned ground are integral to its maintenance through their interactions with the processes of run on and runoff. These differences are thought to maintain vegetation banding. Thus a study of shrink-swell characteristics of the soils of patterned ground areas will add to our understanding of the processes related to their maintenance, particularly if it can be linked to work on run-on and run-off features and the formation of this phenomenon.

There is also a relationship noted in Dunkerley & Brown (1995) between the amount of vegetation and the location and density of crabhole-like features. These pipe-like depressions, centered in a hollow, are usually around 35 cm in diameter and may reach sizes of 100 cm (Macdonald 1999). They are surrounded by concentric cracks and are found only in the vegetated zones. They may be related to shrink-swell activity in the soils or sodicity related dispersion, either independently or in concert.

Dunkerley & Brown (1995) concluded that the sorting of stones that they observed by size, with the smallest material existing the furthest down the slope, is a relic feature from some previous transportation system. However this may also be a reflection of increasing soil depth and the change in the soil's capacity to lift an object of a given size to the surface. It could be that larger material can only be lifted to the top of a shallow profile. Dunkerley & Brown (1995) feel that there is no possibility of down slope movement being the source, as they conclude that such activity is not presently occurring. Their conclusion is drawn from the lack of stones in the vegetated zones and the observation that the sorting crosses the boundaries between bare zones, being a slope sized feature rather than existing in a single band.

Dunkerley & Brown (1995) suggested that vegetation banding formed after the last glacial maximum as the result of increasing rainfall, causing shrink-swell related heave, which concentrated the stones into the bands they currently occupy. Various forces acting upon the soil, to control the directions of heave, have caused contour parallel banding to form (Dunkerley & Brown 1995). Macdonald (1999) concluded that the soils were around 16,000 years old based on stratigraphic relationships with other dated soils.

Work by Macdonald (Macdonald *et al.* 1999, Macdonald & Melville 1999, Macdonald 1999) has shown that there is a variation in the concentration of soluble cations between the zones of patterned ground. Potassium is higher in the vegetated zones with a marked decrease in the bare zones, calcium and magnesium are enriched in relation to sodium in the vegetated zones, but are similar in concentration in the bare zones, while sodium is high in the bare zones. These types of variations are important to a study of soil shrink-swell because different interlayer cations have different effects on volume change in clays.

Macdonald (1999) discusses the idea that the stones found on the surface of the bare areas at Fowlers Gap may have originally been brought to the surface and be maintained at the surface by shrink-swell related heave. Paddocks near the study sites have been shown to have smectitic soils (Macdonald 1999). Macdonald's work suggests that by weight there is little difference between the stone content of the subsoil under the different zones. He does not outline the nature of the subsoil stones and it may be that there is variation in size and shape of stones between the zones. The mechanisms for the creation of the stony bare areas are not well understood. This study seeks to clarify the situation.

AIMS

1. To explain through a combination of laboratory and field investigations the patterned ground phenomenon at Fowlers Gap NSW.

2. To determine the variations within an area of patterned ground in shrink-swell behaviour and the relationship of these variations to exchangeable cations and other variables reported from nearby sites

METHODS

Field Work

Field work was completed in two 2 week blocks from the 1st to the 15th of June and the 3rd to the 16th of August 2003. These followed a short scouting trip during March. The June trip was devoted to sample collection and the August trip to mapping work.

Three sites were selected and are herein referred to as sites 1, 2 and 3. They were selected for the clarity of banding visible on the ground even under drought conditions and accessibility by the loader used to excavate the trenches. Sites 1 and 2 are located in the Sandstone Tank paddock and site 3 in the Air Strip paddock. Based on the previous work, aerial photography and consultations with the station staff these sites have not undergone any attempts at contour furrowing or previous trenching. Three trenches approximately 20 x 2 x 2 m were excavated via the use of a loader rented from Fowlers Gap.

Samples were taken in the middle of each band as determined by reference to the surface features of the band and at the boundaries between bands. Down the profiles samples were taken from each layer and in thick layers every 20 cm in that layer. Both bag samples for laboratory work and boxes or clods for textural analysis were collected. Other box samples were taken where an interesting feature was observed such as stones in the soil.

Field descriptions of the soil were made using the Northcote system and Munsell colour charts. The profiles were photographed at each stage and logs drawn for each sample's profile.

Laboratory Work

Samples have been analysed using several different techniques:

1. X-ray Diffraction (XRD): XRD is being used to determine the mineralogy of the material including clay analysis and bulk compositions for most samples;
2. Geochemistry:
   - Bulk Geochemistry: This is being assessed using x-ray fluorescence at the Geoscience Australia Laboratories to help in the identification of mineralogy;
   - Exchangeable Cations: These are being tested for using the standard tests to determine the relationship of these elements to clays in the site and to determine if the clays could cause variations and form a link between cations and soil mineralogy; and,
   - Carbonates and Gypsum: The presence of these minerals was tested for in the field; further tests to determine their concentrations are being done. All tests for these are being done using standard testing, with a titration for carbonates if a field acid test reveals their presence. These are being tested to allow for linkage of relationships to shrink-swell clays to other studies and to characterise the soils. Results will also be compared to those obtained via XRD.
3. Dispersion: Dispersion testing will be done using the standard test to determine if crabholes may be dispersion related and to characterise the soils;
4. pH: All bulk samples are being tested using an universal indicator based soil testing kit;
5. Particle Size analysis: Samples were sent to the laboratory at Geoscience Australia;
6. Thin sections and Scanning Electron Microscope (SEM): These methods are used to examine the microscopic soil textures for indications of shrink-swell activity. SEM will be used should thin sections prove to have too poor a resolution to look at these structures; and,
7. Shrink-swell capacity testing: This is being carried out using the modified linear shrinkage test as outlined in McKenzie *et al.* (1994).

RESULTS

Preliminary impressions are that at site 3 there is a combination of processes occurring (see Figure 2) to produce the surface stones, while for sites 1 and 2 stone movement models are currently being developed

I would anticipate that at sites 1 and 2 it will be found that the processes are similar to those in action at site 3. Although I will not be able to calculate a rate of stone uplift, I would imagine, as the number and heaving capacity of swell events will be the main factors controlling the development of these bands, such rates would be very slow in arid zone areas such as Fowlers Gap. I would also anticipate finding that the nature of the soils will give some indication of formation processes and that this indication will be that shrink-swell in the soils plays some part in the formation of the banding.

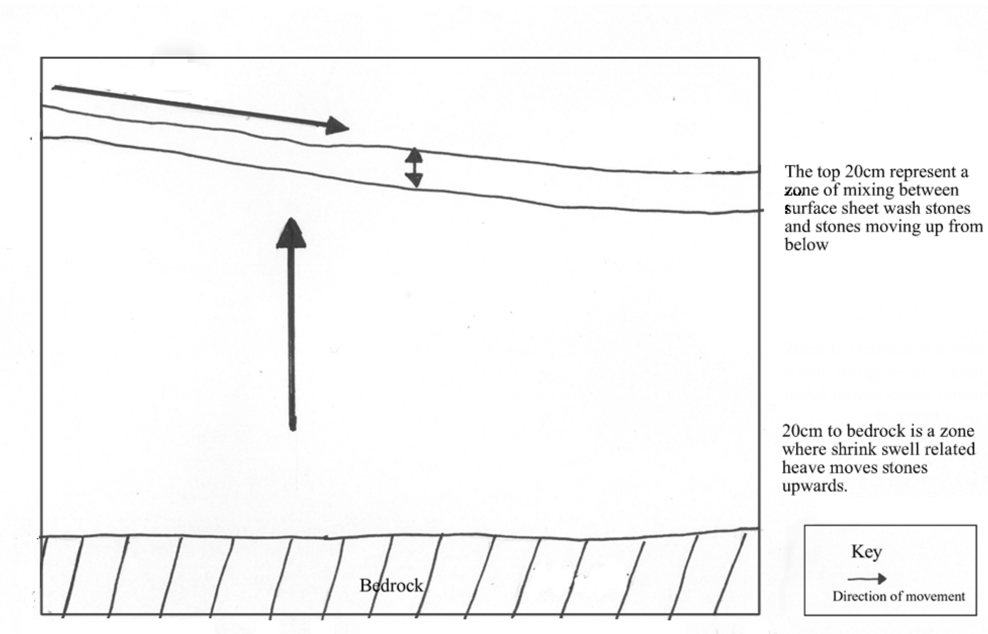

Figure 2: a schematic sketch of the stone movement at site 3.

DISCUSSION

While we have an understanding of how patterned ground systems at Fowler's Gap are maintained, we previously had little idea as to how they were formed. Shrink-swell in soils has been suggested as a means of formation (Mabbutt 1978). This research will either establish the possibility of the formation of patterned ground via shrink-swell related activity in the soil or it will eliminate this as a formation mechanism at Fowlers Gap. Either way it has implications for the understanding and management of these systems. If we understand how these areas are formed it may be possible to apply this knowledge to the restoration of degraded areas of patterned ground. An understanding of these areas will also help to sustainably utilise large expanses of Australia. The identification of stone movement via soil heave also has implications for archaeology in that the methods here used provide a guide to archaeologists for testing for this taphonomic process, the presence of which would have an impact on archaeological interpretations from the area.

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