DRY SALINE LAKEBEDS AS POTENTIAL SOURCE AREAS OF AEOLIAN DUST: STUDIES FROM THE CENTRAL GREAT PLAINS OF THE USA AND SE AUSTRALIA

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INTRODUCTION

The genesis, erosion, transport and deposition of aeolian dust particles have major implications in environmental management, soil-landscape processes and landscape evolution. A key component of this study is an understanding of the generation of these aeolian dust materials in the source areas. Recently, there has been an increasing interest in the role of dry lakebeds and deflation basins in the African continent as potential source areas for dust. For example, studies have highlighted the Bodélé depression, Chad, in the Sahara, as the world's largest single source of dust (Washington *et al.* 2006). Australian studies also indicate that dust particles with a range of sizes are derived from both floodplain areas in the Murray-Darling Basin as well as a range of internally draining dry lake beds/playas/mudflats in both South Australia (e.g. Lake Eyre and Lake Frome) and Victoria (e.g. Lake Tyrrell and Lake Corop) (McTainsh 1989, Dare-Edwards 1984). Several of these studies have also described the occurrence and genesis of clay pellets and the potential for this material to be subsequently transported over a range of distances downwind as aeolian dust. As these source areas of pellets are commonly saline and contain salt crusts, the pellets also represent a potential source of salt-rich aeolian dust that may contribute to salinisation downwind (Mees and Singer 2006). However, to date very little is known about the potential for similar sources of dust to occur in dry lakebeds and/or adjacent dunes in the USA. This paper reports a preliminary study into the potential for clay pellets to be generated under saline condition in lakebeds in the Laramie Basin, Wyoming, USA, from where they may be blown downwind as aeolian dust. Comparisons are also made with a similar evaporation basin in Australia.

EXPERIMENTAL

During May 2006, samples of salt crusts and clay pellets were collected from a range of lakes (either dry or partly filled) in the Laramie Basin, Wyoming, USA (Figure 1). The clay pellets were sampled from either the lakebeds, coppice dunes immediately downwind of the lakebeds, or adjacent hill slopes. A preliminary study was made into of a subset of these samples. The samples consisted of clay pellets collected from both the lakebed and coppice dunes at Diamond Lake. A sample of shale pellets was also collected from a hill slope adjacent to Hutton Lake. The shale pellets represents a potential external source of pellets which could be transported into the lake by slope wash, and then entrained from there by wind. Clay pellets of parna (aeolian dust) collected from a lunette adjacent to a similar type of evaporation basin in northern Victoria (Corop Lake) were also included in the study (Butler 1956). Clay pellets occurring near or in lunettes in northern Victoria have been previously described in detail by Bowler (1983) and Mays *et al.* (2003). The samples were analysed by the following methods: x-ray diffraction (XRD), scanning electron microscopy (SEM), and particle size distribution (PSD) using laser diffraction. The pH and EC were also measured on 1:5 soil-water extracts of the pellets. The PSD measurements on the pellet samples from Diamond Lake and Corop Lake were done on both the original samples and on samples that had been sodium saturated in the laboratory.

RESULTS

Preliminary XRD results indicate that the dominant minerals present in the salt crusts of the dry lakebeds in the Laramie Basin are thenardite (sodium sulfate: Na_2SO_4) and/or epsomite (magnesium sulfate: $MgSO_4.7H_2O$). Two sodium-magnesium sulfate minerals, konyaite ($Na_2Mg(SO_4)_2.5H_2O$) and blödite ($Na_2Mg(SO_4)_2.4H_2O$), were also present as minor components. Calcite (calcium carbonate: $CaCO_3$) is only a minor component, if it is present at all. This composition of salts is different to that found at Lake Eyre in South Australia and Lake Tyrrell in Victoria, where the salts associated with the pellets were dominantly halite (sodium chloride: NaCl) and gypsum (calcium sulfate: $CaSO_4.2H_2O$); only minor amounts of thenardite occurred at Lake Eyre (Bowler 1983).

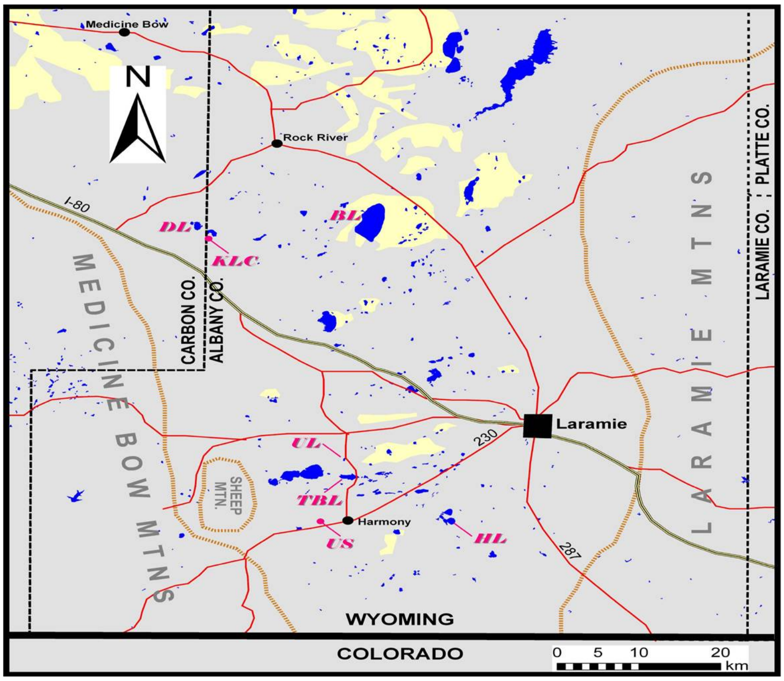

Figure 1: Distribution of lakes in the Laramie Basin, Wyoming, sampled in the study; DL and HL represent Diamond Lake and Hutton Lake respectively.

Table 1 compares the pH and EC of 1:5 soil water extracts of pellets from the four sites. Apart from the Corop Lake pellets, all the other pellets contained high amounts of salts (EC > 4 dS/m). The low pH from Hutton Lake indicates acid sulfate weathering of finely disseminated pyrite in weathering Cretaceous shales around the basin.

Table 1: pH and EC measured on 1:5 soil-water extracts of the pellets.

Sample	pH (1:5)	EC (1:5) (dS/m)
Diamond Lake	8.9	5.6
Diamond Lake coppice dunes	8.4	4.2
Hutton Lake	3.9	7.7
Corop Lake	10.4	0.5

The PSD measurements in Figures 2 and 3 compare the stability of the pellets from the four sites, i.e. Diamond Lake, Diamond Lake Coppice Dunes, Hutton Lake and Corop Lake, when samples are shaken continuously in water for up to 150 minutes. The pellets from Diamond Lake, Diamond Lake Coppice Dunes and the Hutton Lake shale pellets are a lot more resistant to breakdown into fine silt particles (< 20 µm) than the pellets from Corop Lake (Figure 2). Sand-sized aggregates (> 63 µm) in those samples are also more stable than those from Corop Lake (Figure 3).

The PSD measurements (< 20 µm fraction) in Figure 4 compares the stability of the clay pellets from Diamond Lake and Corop Lake (with and without sodium) when samples are shaken continuously in water for up to 150 minutes. The clay pellets from Diamond Lake are much more resistant to breakdown into fine silt particles (< 20 µm) than the clay pellets from Corop Lake. Sodium saturation greatly accelerated the breakdown of the Corop Lake clay pellets, but had no apparent effect on the stability of the Diamond Lake clay pellets. The greater stability of the Diamond Lake clay pellets (with or without sodium saturation) was also demonstrated by the greater resistance to breakdown of the sand-sized aggregates (> 63 µm) compared to the sand-sized aggregates from Corop Lake. Sodium saturation of the Corop Lake clay pellets caused an immediate breakdown of these aggregates on immersion in water (unpublished data).

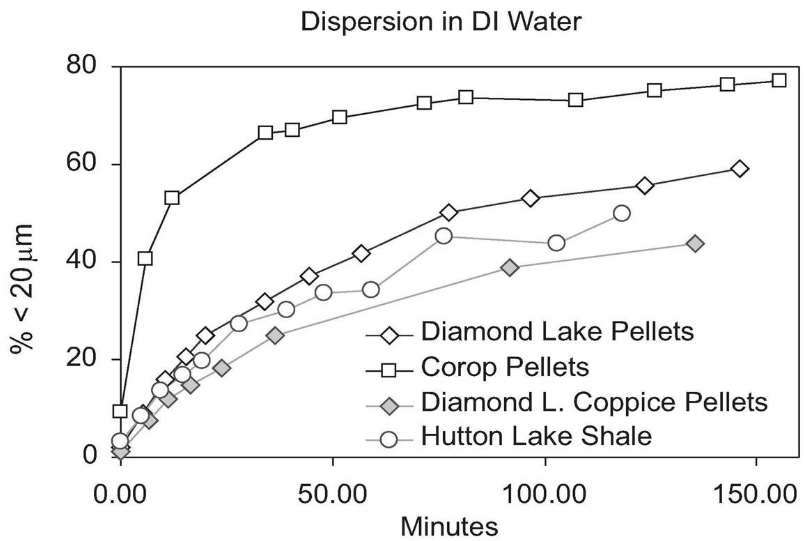

Figure 2: Breakdown of pellets into fine silt particles (< 20 µm) when shaken in water.

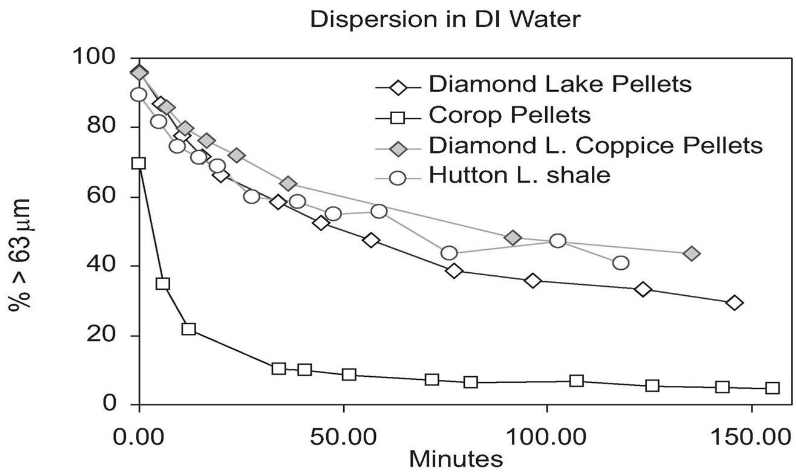

Figure 3: Breakdown of the sand-sized aggregates (> 63 µm) in pellets when shaken in water.

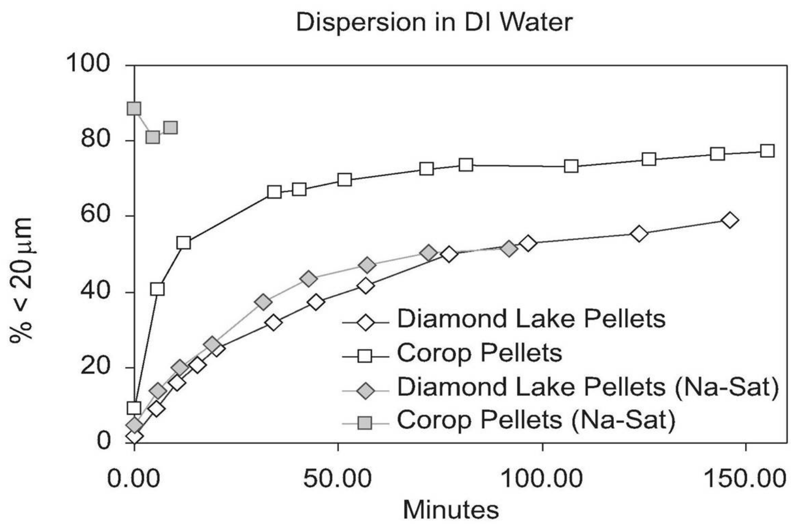

Figure 4: Breakdown of clay pellets from Diamond Lake and Corop Lake into fine silt particles (< 20 µm) (with and without sodium saturation) when shaken in water.

When SEM images of the pellets from each of the sites are compared, the pellets from Diamond Lake, Diamond Lake Coppice Dunes, and the Hutton Lake shale appear to be more tightly aggregated (and larger) than the more loosely aggregated pellets from Corop Lake (Figure 5).

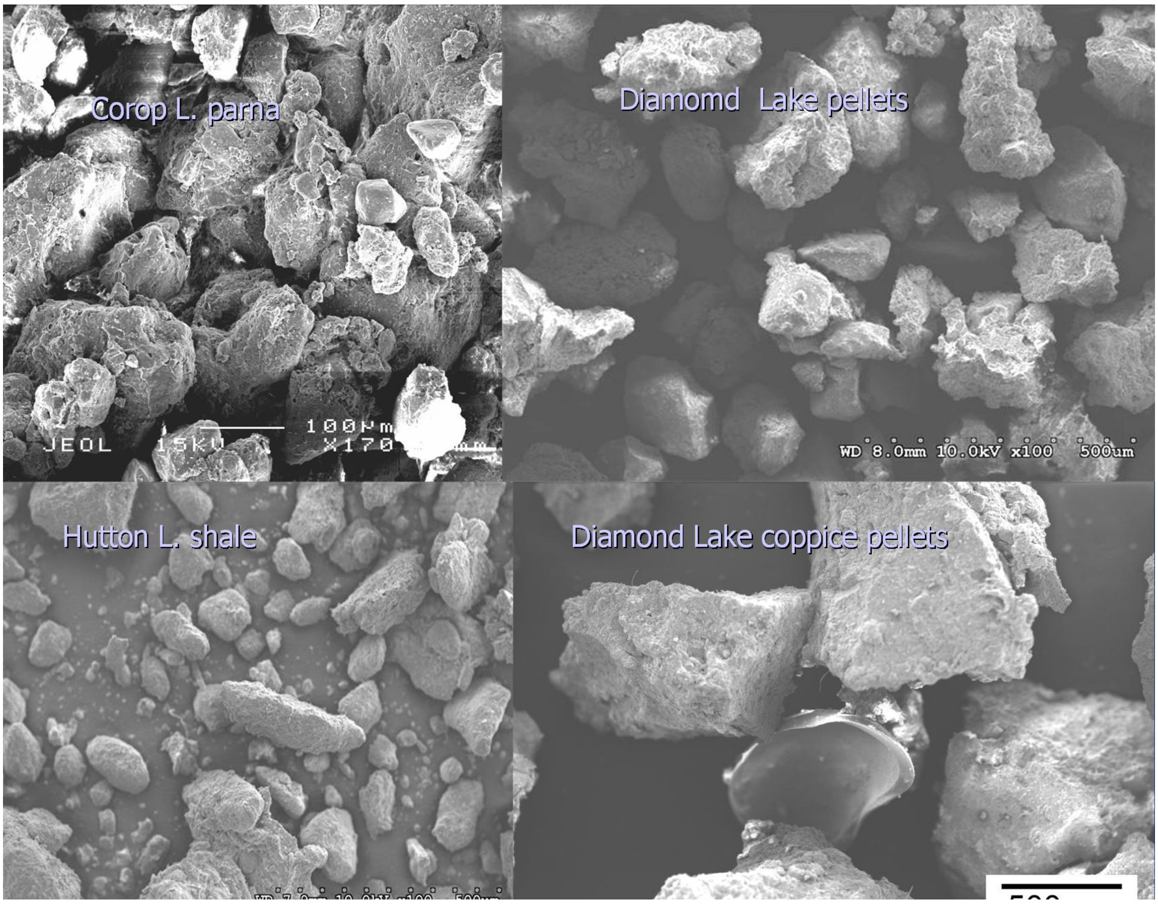

Figure 5: Scanning electron micrographs of the pellets from Corop Lake parna, Diamond Lake, Diamond Lake Coppice Dunes and Hutton Lake shale.

DISCUSSION

The greater stability of the pellets from Diamond Lake, Diamond Lake Coppice Dunes, and Hutton Lake shale compared to the pellets from Corop Lake, may be explained by their higher salt content and their apparent greater degree of aggregation (and hence lower permeability). When the pellets are stirred continuously in water, these factors would cause the salt content in the pores to remain high enough to prevent dispersion until after a long circulation time. In contrast the lower salt content of the less aggregated Corop pellets is rapidly depleted, and so they break up and disperse more rapidly. The difference in stability of the clay pellets from Diamond Lake and Corop Lake does not appear to be related to their exchangeable sodium content, as sodium saturation did not reduce the stability of the Diamond Lake clay pellets. It is further postulated that the very stable Diamond Lake clay pellets are formed from detrital particles derived from local shale bedrock being washed into the lake beds, flocculating under the high saline conditions, and then undergoing extreme drying to subsequently form the very dense clay pellets. The pellets are then available to be wind-entrained and transported short distances by saltation, as demonstrated by the occurrence of similar pellets in coppice dunes downwind of the exposed lakebed. This mechanism for the formation of clay pellets differs from that of Bowler (1983). Bowler's mechanism involved the role of salts, especially halite, in providing the active efflorescent mechanism, which physically breaks up the near surface clays into pellets preparatory for deflation. Given their stability in water, the shale pellets from hill slopes around Hutton lake could potentially be reworked into the lake by slope wash, and remain intact enough for subsequent wind entrainment, providing yet another possible mechanism for aeolian pellet formation. The lake deposits investigated in this study are considered ideal study sites as they are easily accessible and act as model basins to study processes of the formation of salt-rich aeolian dust particles and their subsequent transport. These results have major implications for the possible sourcing of aeolian materials and salts for both past and current land formation processes.

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