

Spherites in yellow brown Kandosols in south Western Australia.

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Abstract

Spherites are strong rounded clay aggregates with characteristic internal fabrics that occur in sandplain soils in south Western Australian. Spherites are composed of dense kaolinitic clay that maybe stained with iron oxide and they are of similar size to associated quartz sand grains (mostly 250 µm to 1 mm). Four spherite types have been recognised and possible origins identified: playa spherites which are dense, smooth sided and contain clay and silt size quartz grains; regolith spherites which have a nucleus of lateritic regolith such as angular quartz grains; composite spherites which have a playa spherite nucleus which is coated with clay and iron oxide in concentric rings and with embedded quartz grains; biospherites formed by soil fauna. The abundance of each spherite type and their distribution within soil profiles has been determined and this information may assist in the interpretation of soil development on the sandplains of south Western Australia.

Key Words

Spherite, fabric, quartz grains, clay matrix, scanning electron microscopy.

Introduction

Spherites (hard, round sandsize clay aggregates of various compositions) were first described for a sandplain soil from Merredin in the central wheatbelt of south Western Australia (Stace *et al.* 1968). They were considered to have formed in Tertiary laterites and had experienced minor colluvial transport. An alternative view is that spherites are wind transported lacustrine clay derived from the surface of drying playa lakes (Killigrew and Glassford 1976). Kew and Gilkes (2010) observed spherites up 80 cm depth in a yellow brown Kandosol (Isbell 1996) from the sandplain (MacArthur 1991). Spherites were not present in the saprolitic subsoil materials indicating that spherites have an exotic origin and had been introduced into the soil profile. Observations of spherite morphology indicate that some spherites may be faecal pellets or other biologically fabricated material. To date no systematic study has been made of the morphology of spherites. This paper outlines the first description of spherite morphology for soils of the south Western Australian wheatbelt. The findings provide information on the development of sandplain soils of south Western Australia.

Methods

Sample location and sampling method

Intact cores (4 cm in diameter and 2 cm thick) were collected from yellow brown Kandosols at Bodallin in the central wheatbelt of south Western Australia. Soils were excavated to a depth of 1.5 m with a backhoe and undisturbed samples were collected from the pit face within the top 50 cm of the profile.

Polished thin sections and scanning electron microscopy

Polished thin sections of resin impregnated soil were prepared. The fabric was described using optical microscopy and the terminology of Bullock *et al.* (1985) and Kew and Gilkes (2010). Energy dispersive X-ray spectrometry (EDS) was used to determine the spatial distribution of elements in the soil clay matrix and spherites within each thin section using a Jeol 6400 scanning electron microscope operating at 15 kV with a 5 nA beam current. The shapes of sand grains (quartz) and spherites were measured using Image-J software (Rasband 1999) analysis of scanning electron microscope (SEM) micrographs.

Results

Occurrence of spherites

Spherites in soil profiles in south Western Australia may have originated as wind blown clay aggregates from playa lakes (Killigrew and Glassford 1976) in the paleochannel drainage system within this region (Figure 1). The current prevailing wind direction in south Western Australia is from the south west and wind blown clay would be expected to be deposited to the east of paleochannels. Bodallin is located 80 km east of a major paleochannel and spherites occur to a depth of 50 cm in these windblown sandplain soils. However, as discussed above spherites may also have been formed by other processes.

Fabric of spherites

Thin sections of the yellow brown Kandosol at Bodallin show a class 3 fabric arrangement of clay matrix and quartz grains (Kew and Gilkes 2010). That is, greater than 50% of sand grains are coated with clay, there are 20 to 30 % structural bridges (clay) between quartz grains and there is less than 30% isolated clay matrix (Figure 2). The mean percentages of quartz grains, voids, clay matrix and spherites were measured using Image J software of scanning electron micrographs and show the soil to be composed predominately of quartz grains (39%) and clay matrix (41%) with voids (13%) and spherites (7%) being less abundant (Table 1). The sizes (feret) of quartz grains and spherites are similar (142 and 132 μm respectively) which is consistent with aeolian transport and size sorting. The mean circularity of quartz grains and spherites is the same (0.51) indicating both are somewhat elongated rather than spherical (circularity = 1). The greater variability in spherite circularity (SD = 0.13) maybe due to the varied origins of spherites.

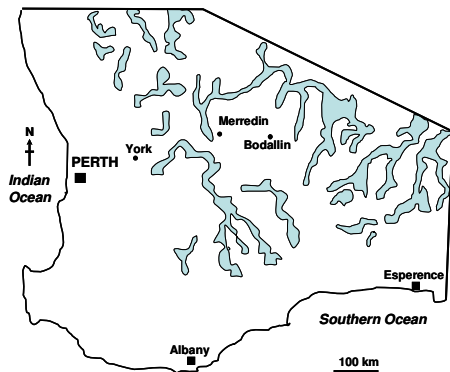


Figure 1. Paleochannels of the south Western Australian wheatbelt (McArthur 1991). Bodallin is approximately 80 km east of a major paleochannel from which spherites may have been derived.

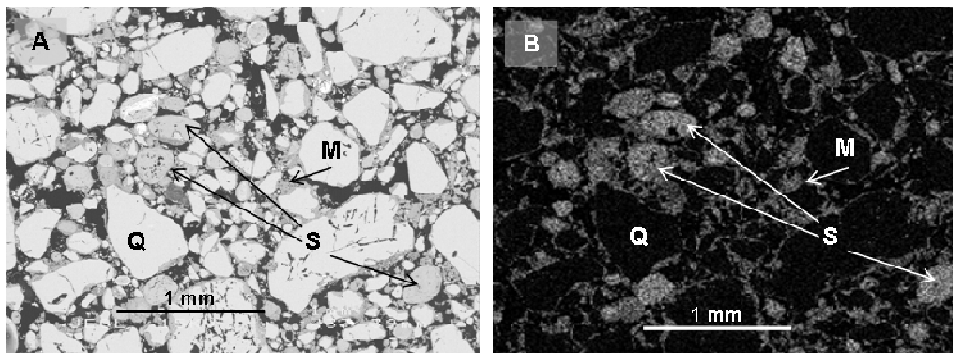


Figure 2. Representative scanning electron micrograph (A) and aluminium map (B) of a yellow brown Kandosol with class 3 fabric from Bodallin. The fabric is poorly sorted and spherites are quartz grain size. The aluminium element map shows the spherites are well rounded and their strong intensity in the aluminium map is an indication they have a higher density than the surrounding clay matrix. Q = quartz grain; S = spherite; M = porous soil clay matrix; V = void.

Table 1. Percentages of quartz grains, voids, clay matrix and spherites in 25 polished thin sections from Bodallin.

	% quartz grains	% voids	% clay matrix	% spherites
mean abundance (N=25)	39	13	41	7
SD	3	3	5	2
mean feret (μm)	142	-	-	132
SD	18	-	-	16
mean circularity	0.51	-	-	0.51
SD	0.02	-	-	0.13

EDS analysis of the clay matrix and spherites in the Bodallin soil samples shows that both materials have the ideal kaolin composition (Figure 3). That is all EDS analysis points lie on the kaolin line in the ternary plot which represents the $\text{Al}_2\text{O}_3:\text{SiO}_2$ ratio for ideal kaolin diluted by various amounts of Fe_2O_3 . Clay matrix appears more SiO_2 rich due to embedded silt size quartz ($< 20 \mu\text{m}$) while transported spherites are Fe_2O_3 enriched. The total oxide weight percentages (Table 2) from EDS analysis are less than 100% because

materials are porous (Tretyakov *et al.* 1998), so these data provide a measure of porosity in the analysed volume (Kew and Gilkes 2007). Dense clay has a higher oxide weight percent than porous clay. Spherites are more dense (less porous) than the clay matrix of these soils which may reflect the formation of spherites in alluvial clay in playa lakes by a process of aggradation during transport over the playa surface.

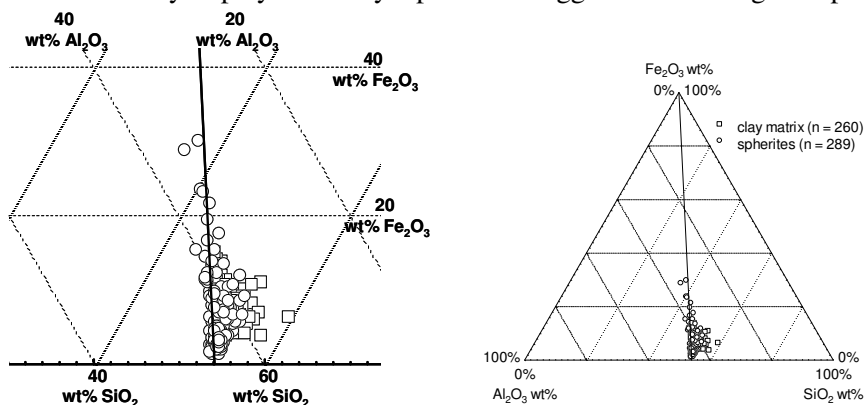


Figure 3. Normalised ternary plot of Al_2O_3 , SiO_2 and Fe_2O_3 wt% determined from EDS analyses. The clay matrix and spherites of Bodallin samples are composed of kaolin clay with minor dilution by iron oxides. The kaolin line is based on the Al_2O_3 : SiO_2 ratio for ideal kaolin and is represented by the line drawn to the Fe_2O_3 apex which represents kaolin mixed with increasing proportions of iron oxide.

Table 2. Mean weight percentage of Al_2O_3 , SiO_2 , Fe_2O_3 and oxide total (EDS spot analysis) for clay matrix and spherites from Bodallin. Spherites have a higher total oxide wt% than clay matrix which is indicative of spherites being more dense than matrix (Kew and Gilkes 2007).

	EDS weight %				Normalised oxides ($\Sigma = 100\%$)			N
	Al_2O_3	SiO_2	Fe_2O_3	Total Oxide	Al_2O_3	SiO_2	Fe_2O_3	
clay matrix	27	35	5.0	68	41	52	8	260
SD	4.1	4.9	1.7	9.3	1.3	1.7	2.3	
spherite	36	43	3.5	83	43	52	5	289
SD	3.6	4.0	3.4	6.3	2.0	2.4	4.1	

Spherite morphology

A spherite classification is proposed (Figure 4). Spherites that developed in argillaceous playa lake sediments which consisted mostly of kaolinite and fine silt quartz grains have been termed “playa” spherites (micrographs A and B, Figure 4). Playa spherites are dense with little evident porosity, smooth sided and contain silt size quartz grains. These spherites are generally coated with the more porous soil matrix clay. Two types of spherites form around a nucleus of mixed origin and these are termed “regolith” spherites and “composite” spherites. Regolith spherites have fragments of granitic saprolite as a nucleus which are coated with argillaceous clay that maybe iron oxide enriched. In the example shown the clay has infilled the jagged edges of a 250 μm elongated and angular quartz grain forming a more rounded object which was subsequently transported (micrograph C). Composite spherites have a playa spherite nucleus which is commonly coated with several concentric layers of varied composition clay with embedded quartz grains (micrograph D). Spherites commonly contain more iron than the associated clay matrix, presumably because the playa clay sediment was relatively rich in iron oxide. Spherites may also have developed by biological activity within the soil and these spherites are termed “biospherites”. They have distinct morphologies, for example worm cast biospherites (micrographs E and F in Figure 4) form elongated, highly porous, silt size quartz grain enriched spherites that exhibit typically extruded clay lamellae.

Conclusion

The proposed spherite classification is based on morphology and postulated origins of formation. Playa spherites are formed from argillaceous deposits, mixed spherites may have a granitic saprolite or a playa spherite nucleus which maybe coated with iron oxide rich clay and or quartz embedded clay, while biospherites have a biogenic origin. The abundance and depth of spherite types within a soil profile may help with interpreting the formation of sandplain soils.

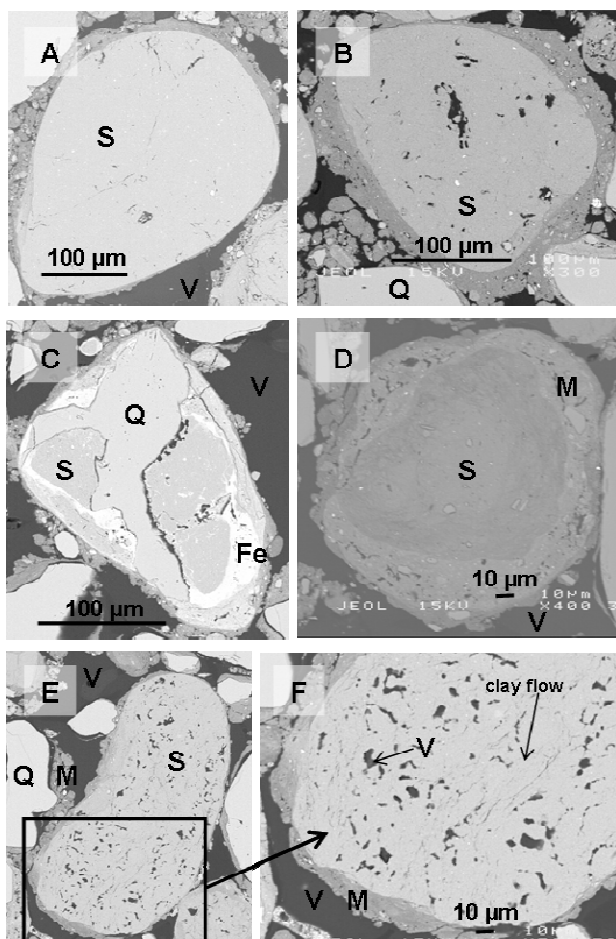


Figure 4. Spherite classification. Playa spherites are dense, smooth sided clay aggregates with minor silt size quartz grains (micrograph A and B). Mixed spherites may form with a granitic saprolite nucleus such as an angular elongated quartz grain (micrograph C) or playa spherite nucleus (micrograph D). They are commonly coated with iron rich clay or may contain consecutive rings of porous clay matrix with embedded quartz grains. Biospherites have been formed by soil fauna such as worms (micrograph E) and extruded clay flow lamellae are present (micrograph F). S = dense spherite; Q = quartz; Fe = iron enriched; M = porous soil clay matrix; V = void.

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