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Project: THE EARTH'S OLDEST (~3.4 GA) PALEOSOL?

Project Report:

The 2008 fieldwork season in the Pilbara Craton of Northwestern Australia (Fig. 1) was carried out with the intention of studying the Earth's oldest emergent land surface and a clay- and iron-rich alteration zone below the surface. The major goals of the research were to: 1) map and characterize the oldest land surface (unconformity); 2) discover the origin and continue the characterization of the clay-rich alteration below this surface, specifically to determine whether it represents the Earth's oldest preserved soil (paleosol); 3) investigate the spatial and genetic relationships between the oldest land surface and surrounding clay-rich rock; and 4) investigate the spatial and genetic relationships between the clay-rich rock and iron-rich pods that occur within it. During the 10 weeks of fieldwork 12 locations spanning more than 150 km were visited to carry out the investigation. The fieldwork resulted in the mapping of over 400 m of the ancient land surface, the characterization of a similar distance of the underlying clay-rich rock, the collection of over 200 samples for laboratory analyses, and the exploration of 10s of kilometers of under-investigated ridge lines and geologic features.

The ultimate goal of the work is to determine whether the clay- and iron-rich rock below the oldest land surface in the Warrawoona Group (~3.5 Ga) volcanics is the result of groundwater type laterite forming processes at ~3.4 billion years ago. The initial stages of laterite formation involve processes that occur in most soils. Meteoric water, rich with organic acids, washes through weathering rock, breaking down the alumino-silicate minerals that compose the rock and mobilizing the major elements within these minerals (e.g. Mg, Fe, Ca, Na, K, etc.). A laterite forms when the reduced, metal-rich groundwater meets a source of free oxygen, and the metals oxidize and form a metal-rich duricrust at the level of the groundwater table (Fig. 2). Groundwater-type laterite formation requires three key conditions to occur: 1) a distinct wet and dry season; 2) free atmospheric oxygen; and 3) organic acids to mobilize otherwise immobile metal species. The presence of a lateritic soil beneath the Earth's oldest land surface would suggest that the atmosphere contained significant amounts of free atmospheric oxygen and the surface was colonized by microbial life at 3.4 Ga.

The study region has been divided into 3 major areas: the Strelley Pool Ridge system, the North Shaw Ridge system (Fig. 1), and Nullagine 1 (51 201727E 7602504N). Each of these ridge systems flanks a different granitic dome in the dome and keel structure of the Pilbara Craton (Fig 1). The 3 areas flank the Carlindie, North Pole, and Corunna Downs granitic complexes, respectively

To discover the origins of the clay-rich alteration zone it was necessary to map the unconformity that represents the Earth's oldest land surface. The task was performed at Steer Ridge (50K 0738937E 7655292N), Anchor Ridge (50K 0739391E 7654629N), Trendall Ridge (50K 07399645E 7652199N), ABDP#8 (50K 0726985E 7665322N), and Kosei Ridge (50K 0727303E 7665408N). Over 400m of the unconformity surface was mapped using a GPS unit, compass, and measuring tapes (Fig. 3).

The work has revealed that the Archean surface likely showed low relief (meters) augmented by fault scarps and resistant bedding, such as cherts. One important example of this has been recognized at the ABDP#8 site where a black chert bed, over caused a paleo-topographic high that may have caused the erosion and loss of soft solum (Fig 4). An important concept to be explored during the course of this study is the concept that soft solum was preserved in topographic mids and lows.

The rock underlying the unconformity surface is characterized by thin sediment packages that may represent growth faults, as well as slightly altered volcanics, and clay-rich altered volcanics that may represent preserved soft solum. The majority of the investigated unconformity surface showed that the alteration that caused the clay-rich zones below this surface occurred prior to or synformal with the development of the erosional surface. Overlying the unconformity clasts of soft solum, and a conglomerate with a clay matrix that may represent eroded soft solum could be proof of the temporal relationship. Clay-rich alteration typically containing muscovite crosscuts the unconformity surface into the overlying Kelley Group where faults and other large structural features occur.

The clay-rich alteration zone in the Warrawoona Group is enriched in pyrophyllite, chlorite, clinochlore, and in some regions with minor enrichment of muscovite (Fig. 5). The alteration zone, specifically the pyrophyllite, has previously been attributed to sulfidic alteration associated with the North Pole Dome. However, a recent investigation at Nullagine 1 has shown that the pyrophyllite-rich alteration can be found flanking other granitic domes. Further, a core retrieved from the ABDP#8 site has produced evidence that the Warrawoona Group in the Strelley Pool Ridge system contains a probable paleosol. The evidence shows that the event responsible for the alteration immediately below the oldest land surface is likely a broadly developed paleosol.

At Steer, Trendall, Anchor, Bierf, Kosei, ABDP#8 and Stelley Pool ridges zones of Fe-enrichment have been discovered. Overall there is particularly little Fe-enrichment beneath the unconformity, which is consistent with a groundwater type laterite model. There are three types of Fe-enrichment: Steer type, Trendall Type (Fig. 6), and silica-rich. The Steer type is characterized by massive enrichment that shows Eigen textures, nodular textures, and a lack of residual (parental) rock morphology. The Trendall type is characterized by highly concentrated pockets and bands of hematite-enrichment with clay rich partitions, and the retention of original rock morphology (e.g. pillow structures). The final Fe-enrichment type, silica-rich, is characterized by goethite, hematite, and black silica enrichment that appears to be associated with hydrothermal activity. The Trendall and Steer types are possible laterites, while the silica-rich is likely younger than the clay-rich alteration zone given the cross-cutting relationships of such enrichments, and the association with faults and possibly younger basalt intrusions.

The presence of Fe-rich clasts in the conglomerate overlying the unconformity at Trendall, Steer, and Anchor Ridges are another exciting find. The presence of Fe-rich clasts from Fe-enrichment similar to the Steer or Trendall type enrichments would indicate that the hematite in the pods was present during the erosional event. The clasts have not been positively identified as laterite pebbles, so future work will involve an investigation of samples retrieved during the 2008 fieldwork season.

Another important technique utilized during fieldwork was the measurement of transects taken 90° off strike of the Strelley Pool Formation. These transects were recorded at Steer, Anchor, Trendall, Strelley Pool, and Kosei Ridge. Though these data are still in the early stages of synthesis, the measurements reveal much about how the thickness of the clay-rich zone varies between locations. Typically, the clay-rich zone in the Strelley Pool Ridge system is quite thin (~5m) to absent. The thickness of the clay-rich zone in the North Shaw Ridge system varies from its north to south end, but the overall trend is a thickening of the clay-rich zone towards the southern end with the thickest portions at Bierf Ridge. The thickness of the clay-rich alteration is over 100 m in some locations. However, there is evidence that the variation in thickness may be related to normal faulting and fallen blocks that has resulted in a larger surface exposure of the clays (Fig. 7).

Sampling transects, also taken 90° off strike of the Strelley Pool Formation, were retrieved at Steer, Trendall, Kosei Ridge, Strelley Pool, and Nullagine 1. Sampling transects have been used in past paleosol studies, as well as this study, with great success in demonstrating that a paleosol is present. The most important transects were retrieved at Trendall and Nullagine 1 where it is necessary to show that the chemical and mineralogical variation with increasing depth from the unconformity is comparable to modern soils. Detailed chemical, mineralogical, and petrographic studies are currently underway on these samples.

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