THE DEPOSITIONAL SETTING OF EARTH'S EARLIEST SEDIMENTARY ROCKS. E. Bjonnes[1] and J. F. Lindsay[2], [1]Department of Geological Sciences, Rutgers University, Piscataway, NJ 08854 (emblue@eden.ritgers.edu), [2]Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058 (lindsay@lpi.usra.edu).

Introduction: The c.3.5 Ga Coonterunah Group which is exposed on the Pilbara Craton of Western Australia (Fig. 1) includes one of Earth's oldest and best preserved stratigraphic successions. The succession consists largely of high magnesian ultramafic volcanics many of which are pillowed suggesting subaqueous deposition. One unit within this group, the Coucal Formation, includes a small number of thin but laterally continuous laminated cherts. Here we attempt to determine the origin of these ancient sediments and define their depositional environment.

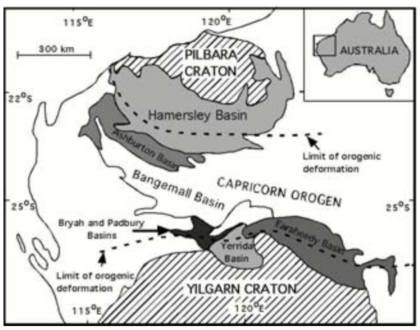

Figure 1. Locality map for the Pilbara Craton.

The Coucal Formation: A detailed analysis was undertaken on a complete 710 m-thick section through the Coucal Formation 30 kilometers west southwest of Marble Bar (Fig. 2). Extrusive volcanics, mostly basaltic in composition, dominate the formation but a small number of units are rhyolitic in composition. Zircons from these more acidic intervals date the formation at 3.515 Ga [1], the earliest dated succession on the Pilbara Craton. Cherts, most finely laminated, occur throughout the formation.

The Volcanic Units: Extrusive ultramafic rocks are the predominant lithology of the Coucal Formation. Based on the pillow structures and fine-grain of these basalts, they likely cooled quickly in a subaqueous environment. Many of the compositions fall with low quartz contents (0-20%) and moderate pyroxene content (30-55%) (Fig. 3). Some of the basalt samples were unusually quartz-rich, and one point was so quartz-depleted that a normative calculation was uninformative and difficult to interpret.

Trace element chemistry can also offer insight into the origin of some basaltic samples [2]. Along with

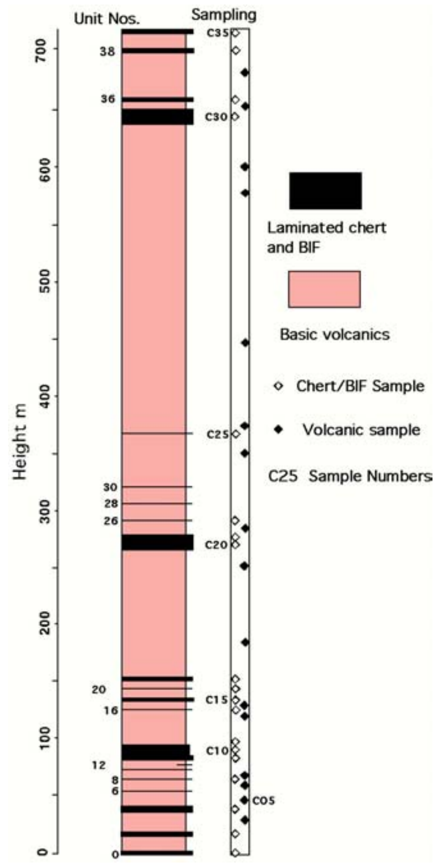

Figure 2. Measured section through the Coucal Formation showing sampling strategy.

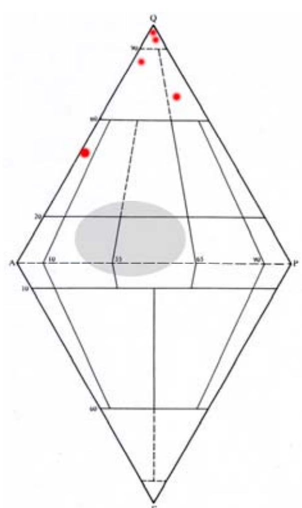

Fig 3: QAPF diagram showing distribution of basalt compositions. The shaded ellipse shows the majority of the compositions. The red dots are the unusual data points.

the silica depletion they suggest that the volcanics have been hydrothermally modified. A zirconium versus titanium crossplot shows the Australian basalts most closely follow the trace element trends of the ocean floor basalts. This data with the texture and grain size of the basalts in hand sample strongly suggest that these basalts originated on the ocean floor.

The Cherts Units: Cherts, most thinly laminated, occur throughout the Coucal Formation although they are more abundant and generally thicker closer to the base and top of the formation (Fig. 2). The 21 individual chert units at the study site vary in thickness from a few centimeters to a maximum of approximately 10 m. Most units are very continuous laterally and despite local faulting, they are distinctive enough to be traced for several kilometers. Eighteen of the 21 units were sampled and polished thin sections prepared for analysis by petrographic microscope and scanning electron microscope (SEM). Ten samples were subjected to whole rock geochemistry using XRF and ICPMS. The cherts are predominantly silica (Mean = $84.8 \pm 14.5\%$, N=10) but also contain a significant but variable amount of Fe, which, under micropetrographic and SEM analysis proves to be largely iron oxides. Fe content varies from 1.1 to 29.4 % (Mean = $8.8 \pm 9.3\%$, N=10). The remaining proportion of the cherts consists of a variety of, at times exotic, elemental components (e.g., As, Ba, Cu, Ni, V, and Zn) in trace but significant amounts. SEM analysis of polished thin sections indicates the presence of an array of exotic mineral throughout the formation consistent with the whole rock geochemistry. Fe-Mg silicates, Ti and Fe sulfides and Mg oxides are present, lower in the formation. Zr, Mn, Cu minerals as well as elemental Au and anhydrite, were also encountered. Reduced carbon is present in all chert intervals.

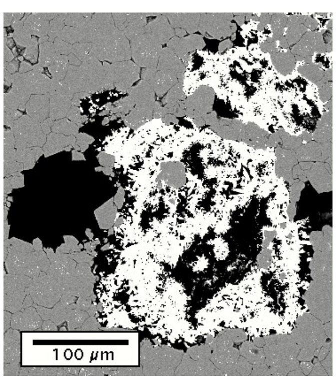

Figure 3. SEM backscatter image of a small vug within the chert matrix containing fans of Fe-oxides crystals.

Hematite frequently occurs as fans of blade-like crystals or simply as massive clumps or stringers in the silica matrix. Some black laminae consist entirely of densely packed iron oxide fans surrounded by silica matrix. Small iron oxide fans 30 to 50 µm in diameter are also present and widely distributed in the lighter colored chert laminae. Small vugs, typically 20 µm in diameter are dispersed throughout the chert matrix. The vugs are lined with the c-axis terminations of quartz crystals which enclose small fans of bladed hematite and small amount of carbonaceous material. In other laminae, the Fe oxides occur as small spheres that are typically 20 µm in diameter. The spheres have magnetite cores with an outer layer of hematite. Fe-oxides also occur in at least two generations of well defined veins that transect the chert laminae at a high angle.

Carbonaceous materials are present in all chert intervals although in relatively low abundances ($0.023 \pm 0.015\%$ total reduced carbon, N=8, analysed by sealed tube combustion). The carbonaceous material occur either disperse in small patches throughout the chert matrix or in close association with iron oxides in vugs and vein fillings.

Rare earth element plus Yttrium (REE+Y) profiles of the cherts are similar to those encountered in other sediments from the Pilbara succession [3] with a significant LREE depletion and, in some samples, a significant Ce anomaly. REE+Y patterns for dolostones from the lower part of the Hamersley Basin succession were analysed as an Archean seawater proxy. The REE+Y chert profiles show little similarity to the Archean carbonate seawater proxy.

Conclusion: The mineralogy of the Coucal Formation bears many similarities to the Apex chert [4]. The predominance of silica and iron oxides and widely dispersed trace amounts of exotic minerals suggest a hydrothermal origin. This is further supported by the "mantle-like" form of the RRE+Y profiles which display light element depletion.

References:

[1] Buick, R., Thornett, J.R., McNaughton, N.J., Smith, J.B., Barley, M.E. and Savage, M. (1995) Nature 375, 574-577. [2] Pearce, J. A. and Cann, J. R., 1973, Tectonic setting of basic volcanic rocks determined using trace element analyses. Earth and Planetary Science Letters, 19, 290-300. [3] Van Kranendonk, M.J., Webb, G.E. and Kamber, B.S. (2003) Geobiology, 1, 91-108. [4]Brasier, M.D., Green, O.R., Jephcoat, A.P., Kleppe, A.K., Van Kranendonk, M.J., Lindsay, J.F., Steele, A. and Grassineau, N.V. (2002) Nature 416, 76-81.