MECHANISMS AND CONDITIONS OF SAPONITE PRODUCTION IN THE PRECAMBRIAN DOUSHANTUO FORMATION. T. F. Bristow and M. J. Kennedy, Department of Earth Sciences, University of California – Riverside, 900 University Ave, Riverside, CA 92521. tbris001@student.ucr.edu

Introduction: In the Yangtze Gorges region of South China, exposures of Doushantuo Formation record sedimentation in an intrashelf basin on the Yangtze Block between 635 and 551 Ma [1]. The Doushantuo Formation is probably best known because it hosts exquisitely preserved spherical multicellular fossils, widely thought to represent embryos of some of the oldest animals fossils [2]. However, sections in the Yangtze Gorges area also contain some of the oldest sedimentary saponite deposits on Earth [3]. This paper documents the clay mineralogy of the Doushantuo Formation, focusing on the mechanisms and conditions in which saponite formed, as well as diagenetic reactions that affected clays during burial. The discussion of formation processes on early Earth may give new insights into the origins of extensive magnesium-smectite deposits found on Mars.

Methods: Clay mineralogy was investigated using X-ray diffraction of powdered whole rock samples and clay extracts of representative samples, as well as SEM observations of broken chips.

Background: Stratigraphic sections of the Doushantuo Formation are between 100-200m thick in the Yangtze Gorges area, and are typically divided into four members (fig.1). Member 1 is the 3-5m thick ‘cap carbonate,’ that consists of vuggy, carbonate and silica cemented dolomictes passing upward into partially disrupted, thinly bedded micritic carbonates. The cap marks the transition from intense icehouse conditions that characterize the middle Neoproterozoic (reviewed by [4]), and in S. China sharply overlies glacially derived diamictites of the underlying Nantuo Formation. The cap is conformably overlain by ~80m of calcareous mudstones and marls with interbedded muddy dolomites and limestones. A predominance of mm-scale, parallel laminations indicate deposition below storm wave-base. In member 3 (~60m thick) cross-bedding and scouring observed in silty dolomites with thin mudstone partings, indicate deposition in shallower water depths. There is a sharp lithological change to organic-rich, silty mudstones of member 4, that are ~10m thick.

Distribution of Clays: Lower Doushantuo Fm. Saponite and its diagenetic products, corrensite and chlorite dominate the clay mineral assemblage and make up to 30% of the bulk rock in samples from the lower 80m of the Doushantuo Formation. Corrensite and chlorite are more abundant in the cap carbonate and the lower part of member 2, with an upward transition to pure saponite. However, the stratigraphic position and extent of the transition varies between sections.

Figure 1. Simplified stratigraphy and mineralogical distribution of the Doushantuo Formation in the Yangtze Gorges.
Upper Doushantuo Fm and ash beds. In contrast, Mg-smectites are absent in the upper part of the formation. Silty mudstones of member 4 contain illite-rich, mixed layer, dioctahedral, illite/smectite (I/S). The clay fraction of thin (<5cm) ash beds occurring within the cap carbonate and at the top of member 4 also consists of illite-rich I/S.

Origin of saponite: A secondary mechanism for the formation of saponite, such as hydrothermal alteration of basaltic detritus [5], or diagenetic reaction between dolomite and Al-phyllosilicates [6] is ruled out because: a) SEM observations show random clay fabrics, which are interpreted as having a detrital origin [7], rather than secondary fabrics such as pore-filling cements or mineral overgrowths, b) the absence of basaltic material in the Doushantuo Formation, and in underlying lithological units in this part of the Yangtze Platform, and c) the purity of saponites in many samples (the reaction between dolomite and Al-phyllosilicates produces corrensite [6]), and absence of saponite in calcareous mudstones of member 3 despite evidence that the entire formation experienced the same thermal history.

The reworking of an older deposit, or erosion of a saponite generating soil as a source of clays is also unlikely given that the monomineralic nature of the clay mineral assemblage through the lower 80m of the formation requires an exclusively saponitic clay source to be maintained and eroded for millions of years – based on current estimates of depositional rates in the Doushantuo Formation [8].

Instead, compositional and textural evidence indicate that saponite formed by neogenesis of original detrital clays. The conversion of Al to Mg-rich phyllosilicates occurs in sedimentary systems under high pH (greater than ~9) or high Mg concentrations. During the Phanerozoic, favorable conditions are found in alkaline lakes or evaporative sabkhas [9, 10, 11]. The absence of evaporites in the Doushantuo Formation leads to two possible interpretations for the presence of saponite: a) deposition in an isolated basin under alkaline conditions, or b) anomalous Precambrian ocean chemistry that was favorable for the process of neogenesis.

Based on this interpretation, the switch to an Al-phyllosilicate assemblage indicates a change in palaeoenvironmental conditions during member 3.

Diagenetic pathways of Al and Mg-smectites: Comparisons of clays in different parts of the Doushantuo Formation also give indications of the relative resistance of Mg and Al-smectites to diagenetic change under the same thermal conditions. Ash beds at the top and bottom of the formation were presumably devitrified and converted to Al-smectites soon after deposition, but were largely illitized during burial. Member 4 mudstones probably originally contained Al-smectite or smectite-rich I/S and followed the same diagenetic pathway. In comparison, many saponite-rich samples from member 2 have not been chloritized. The difference in degree of diagenesis can be attributed to greater thermal stability of saponite [12] and differences in the alteration pathways of trioctahedral and dioctahedral smectites (chloritization vs. illitization) [13]. The host lithology is also an important factor in controlling the degree of chloritization of saponite because Mg or Fe is required for the reaction [6, 14].