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Arabian Plate Precambrian-Cambrian Boundary interpreted in Oman's Ara Group

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The Precambrian-Cambrian Boundary (PCB) was recently interpreted within the Ara Group of the Huqf Supergroup of Oman (Figures 1 and 2), and dated at 542.0 million years before present (Ma) ± 0.3 million years (my) (Amthor et al., 2003; *Geology*, May 2003, p. 431–434). The Ara Group is believed to be coeval with the Hormuz Series salt of the Arabian Peninsula and southwest Iran (Figure 1). In just over two decades, the estimated age of the global PCB has changed by almost 50 million years: 590 Ma (Harland et al., 1982), 570 Ma (Harland et al., 1991), and 545 Ma (Gradstein and Ogg, 1996). This new PCB age estimate from Oman is close to other estimates in Siberia (older than 543.8 + 5.1 to -1.3 Ma) and Namibia (younger than 543.3 ± 1 Ma).

The Oman study combined constraints from biostratigraphy, chemostratigraphy, and geochronology, to calibrate the age of the Precambrian-Cambrian Boundary. Amthor et al. (2003) position the boundary below the A4 Carbonate of the Ara Group, at the top of the A4 Evaporite (Figures 2 and 3). The Ara Group represents at least six carbonate-evaporite cycles (A0 to A6 cycles), and reaches a thickness of up to 2,000 m. The carbonate stringers are typically 50–200 m thick. The original thickness of the intervening evaporites are difficult to estimate due to post-depositional halokinesis. The depositional thickness of the anhydrites may be of the order of 10–20 m, while the halite deposits are many hundreds of meters thick today. The carbonate stringers and the Athel silicilytes constitute important hydrocarbon reservoirs that are encased in the salt.

Below the A4 Carbonate, *Cloudina* and probable *Namacalathus* occur and are similar to other terminal Proterozoic thrombolite-*Cloudina* in Namibia and western Canada. These fossils are not found in the A4–A6 Carbonates. The authors also analyzed $\delta^{13}C$ and $\delta^{18}O$ from more than 350 closely-spaced cores from the Huqf Supergroup. These were used to correlate a marked negative $\delta^{13}C$ excursion in the A4 Carbonate to a nearly identical one positioned at the globally observed PC Boundary.

Two volcanic ash beds in the Birba area that 'sandwich' the interpreted PCB were highlighted in their study (Figure 2). The older bed occurs within the A3 Carbonate, 9 m below its top (sample Mukhaizna-11, MKZ-11). The younger ash bed occurs at the very base of the overlying A4 Carbonate (sample Birba-5, BB-5). This ash bed can be correlated to another seven wells across the Eastern Flank for a distance of more than 60 km (based on the gamma ray signal). Zircon grains from BB-5 (17 samples) and MKZ-11 (12 samples) were used to determine the U-Pb ages of the two volcanic ash intervals. The age of the A4 Carbonate was estimated at 542.0 ± 0.6 Ma, and the A3 Carbonate at 542.6 ± 0.3 Ma.

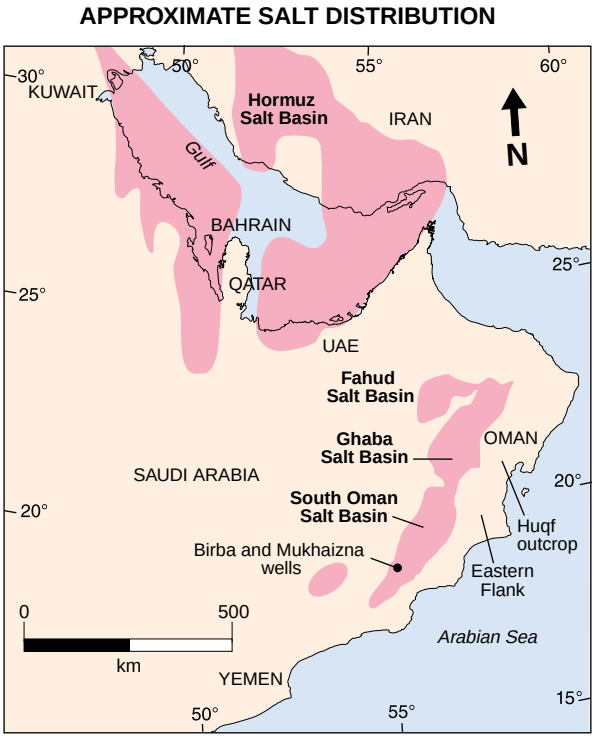

Figure 1: Approximate present-day distribution of infra-Cambrian Ara and Hormuz salt in the Arabian Peninsula and southwest Iran. The Precambrian-Cambrian Boundary is defined in the Birba and Mukhaizina wells in the South Oman Salt Basin (SOSB).

Sharland et al. (*GeoArabia* Special Publication 2; 2001) identified the oldest Cambrian Arabian Plate Maximum Flooding Surface (MFS Cm10) in the lower part of the A4 Carbonate in the Birba Salt Basin. They also picked MFS Cm10 in a 'thin shale' section at the base of the A4 Carbonate in the Birba-1 well (Figure 3). The 'thin shale' is actually the younger ash bed (542 Ma). These authors interpreted MFS Cm10 as the culmination of a series of higher-order sequences or parasequences within a transgressive systems tract (TST).

Schröder et al. (*GeoArabia*, v. 5, p. 176–177, 2000) and Gorman Johnson et al. (*GeoArabia*, v. 7, p. 238, 2002) interpret the Ara carbonate-evaporite cycles as third-order depositional sequences. Schröder et al. interpret the evaporites as platform salina deposits (brine depth less than 5 m), with the halite precipitated in even shallower waters. Gorman Johnson et al. interpret the carbonates as shallow-water platform to offshore-slope / deep-water deposits. The evaporites may therefore represent lowstand and transgressive system tracts (LST-TST), and the carbonates the flooding of the basin (MFS) and highstand system tracts (HST).

The dating of the volcanic ash beds in the A3 (about 542.6 Ma) and A4 (about 542.0 Ma) Carbonates suggests that the intervening A4 Evaporite was deposited in several hundred thousand to one million years. The evaporite-carbonate cycles could therefore correspond to either third- or fourth-order cycles (Matthews and Frolich, *GeoArabia*, v. 7, p. 503–538, 2002). The most likely window for deposition for the Ara Group may fall between 550–530 Ma, such that the Ara and Hormuz salts appear to be infra-Cambrian in age.

In addition to recalibrating the age of MFS Cm10 at 542 Ma (Figures 2 and 3), this stratigraphic note highlights several Precambrian, late Vendian, flooding surfaces near the bases of the A0 to A3 Carbonates, and one in the Athel silicilytes (Figures 2 and 3). These MFS are younger than MFS Pc20 that was assigned by Sharland et al. (2001) to the Shuram Formation, Nafun Group of the Huqf Supergroup.

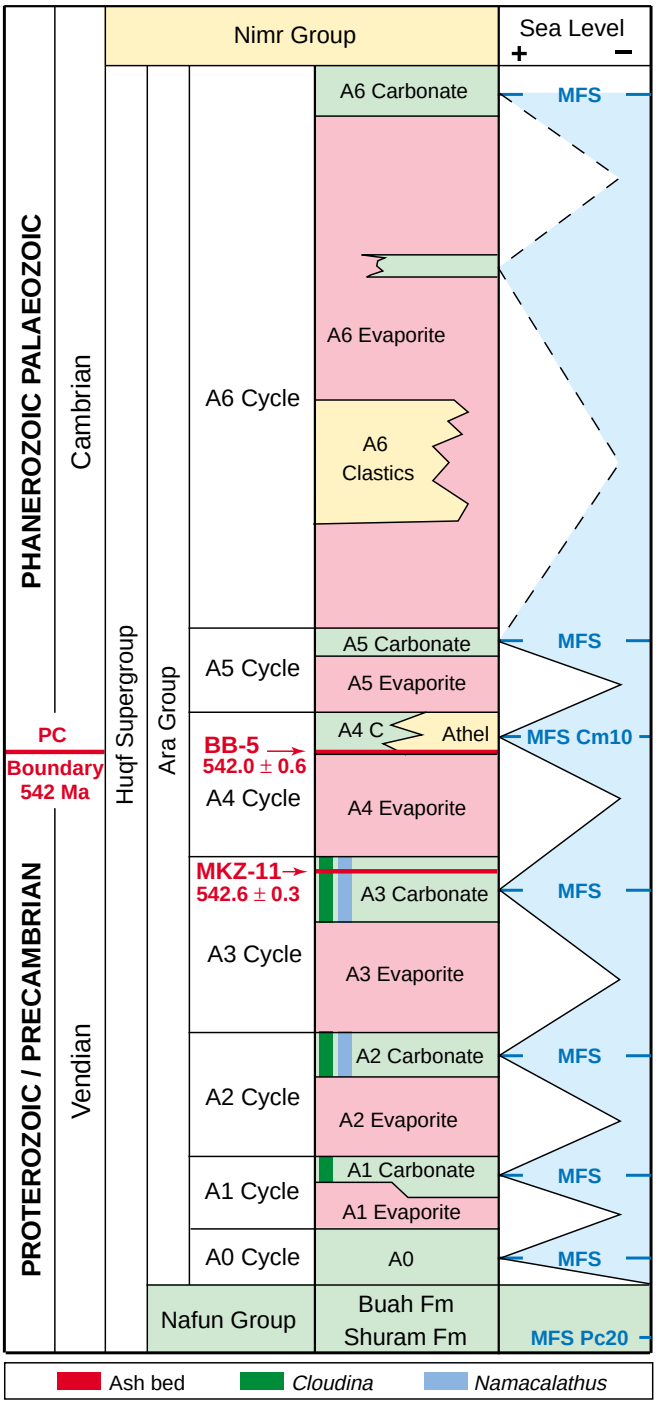

Figure 2: The Ara Group of the Huqf Supergroup of Oman consists of at least six cycles (A0 to A6). The Precambrian-Cambrian Boundary (PCB) is interpreted at the top of the A4 Evaporite (pink) just below the ash bed (BB-5 dated at 542.0 ± 0.6 Ma, shown in red). Terminal-Proterozoic *Cloudina* and *Namacalathus* are present in the A2 and A3 carbonates, but absent above the A4 carbonate; thus marking the PCB at the base of the A4 carbonate. Sea level is indicated schematically as high (+) and low (-). MFS Pc20 is picked in the Shuram Formation of the Nafun Group. MFS Cm10 is the first Cambrian flood and falls in the A4 carbonate (green), dated at about 542 Ma.

A Cambrian MFS is also evident here in the A5 Carbonate (younger than 542 Ma). The A6 Cycle probably contains several flooding events, but these are difficult to correlate laterally due to halokinesis. The A6 Carbonate appears to be the final Ara Group flooding event before MFS Cm20 (approx. 510 Ma) positioned by Sharland et al. (2001) in the Middle Cambrian Burj Formation of Jordan and northwest Saudi Arabia.

References: see **MEGRef** at www.gulfpetrolink.com
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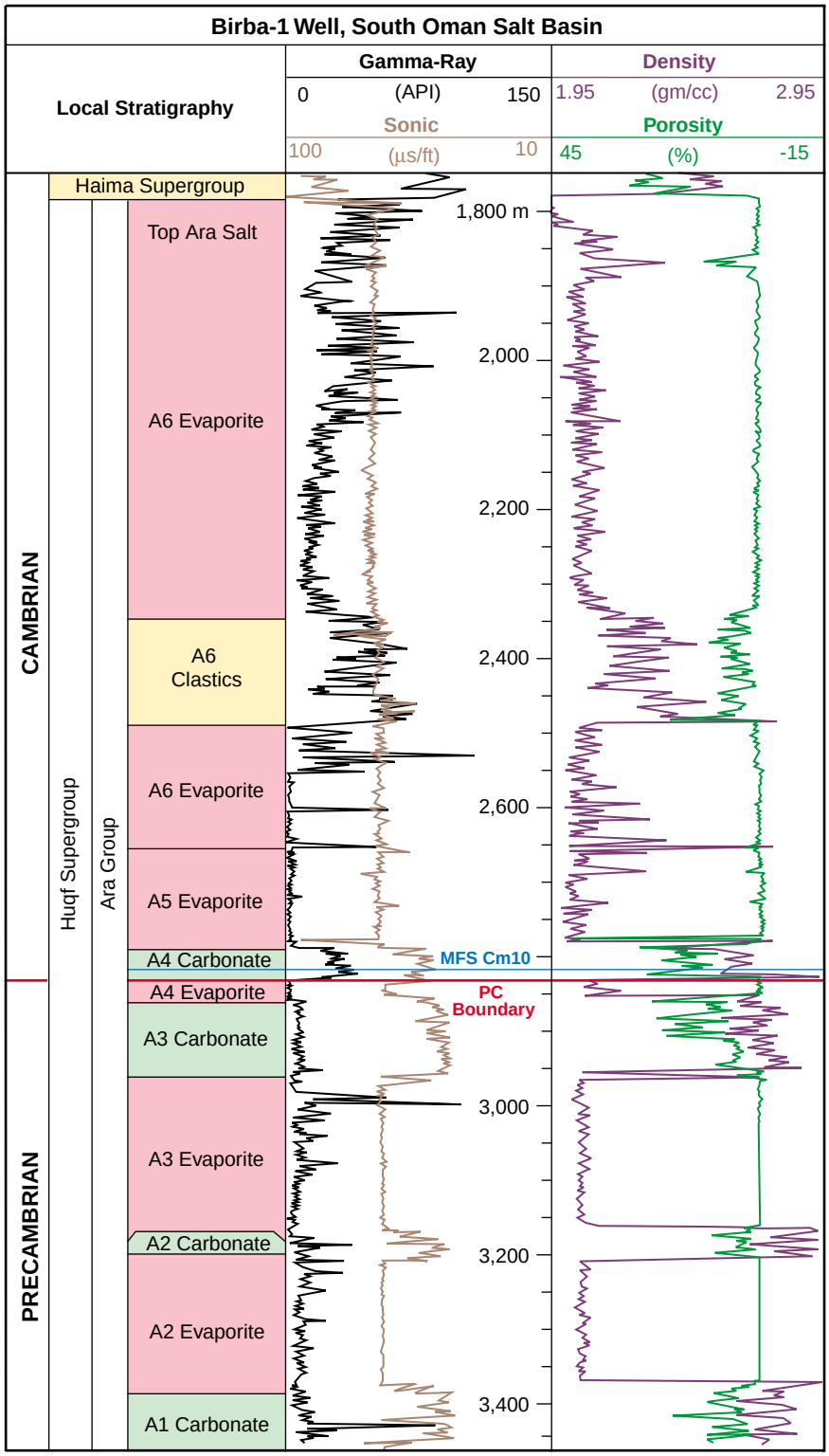

Figure 3: Ara Group cycles in Birba-1 well (latitude 18.31356865N; longitude 55.1007013E) located in the South Oman Salt Basin (SOSB). Birba-1 is the reference well for Arabian Plate Cambrian flood MFS Cm10, now dated at about 542 Ma (Sharland et al., 2001, figure 4.4, p. 133). It is also the reference well for the Precambrian-Cambrian Boundary of the Arabian Plate, here positioned below the thin ash bed at 2,860 m (red line) above the top of the A4 Evaporite. Additional flooding events in Birba-1 occur in the A1 Carbonate, A2 Carbonate and A3 Carbonate. The Ara Group is more than 1,650 m thick in Birba-1 and is unconformably overlain by the continental clastics of the lower Paleozoic Haima Supergroup.