Applications of Chemostratigraphy on a Subregional Scale: Case Study of Permo-carboniferous Sediments, Saudi Arabia

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Abstract

The aim of the following study was to produce a subregional scale chemostratigraphic correlation scheme for the Permo-Carboniferous Unayzah Group, in central and eastern Saudi Arabia. ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry), ICP-MS (Inductively Coupled Plasma – Mass Spectrometry) and XRF (X-Ray Fluorescence) analysis were performed on 30,375 core and cuttings samples from 225 wells, with data acquired for 42-53 elements in the range Na-U in the periodic table.

The Unayzah Group is separated into the glaciogenic Juwayl Formation at the base and the fluvial and aeolian dominated Nuayyim Formation at the top, with the former subdivided into two members, labelled Ghazal and Jawb in ascending stratigraphic order. The Wudayhi Member occurs at the base of the Nuayyim Formation and is succeeded by the Tinat Member.

Previous schemes have been produced for the Unayzah Group and, though many are of high resolution, they are only employed between closely spaced wells. The present scheme is of lower resolution but is applicable over an area extending 550 Km and 350 km in North-South and East-west directions respectively. The chemostratigraphy scheme comprises a hierarchical order of one zone, four subzones and five divisions, based on specific values of ‘key’ elemental ratios including Zr/Ti, Zr/U, Zr/Y, Y/U, U/Th, Gd/Zr, Nb/Yb and Nb/Th. Variations in these parameters primarily relate to fluctuations in sedimentary provenance.

Once chemozone boundaries were identified, their placements were compared with those of formation/member boundaries in 15 reference wells, where the latter were defined confidently, based on sedimentological, palynological and/or wireline log data. For instance, the Ghazal Member roughly coincides with chemozone GHZL, yielding elevated Zr/Ti, Zr/U and Zr/Y ratios. In the reference wells it produces a low ‘blocky’ GR trend and mainly consists of quartz arenites. Sedimentologically, this member is dominated by structureless massive sandstone, with subordinate flat and cross bedding, and occasional shear zones. The overlying Jawb Member comprises chemozone JAW-1 at the base and JAW-2 at the top. The former is similar geochemically to GHZL, but produces lower Nb/Yb values, whilst JAW-2 is characterized by low Zr/Ti, Zr/U and Zr/Y. Chemozone TIN-1 encompasses the Wudayhi and lowermost Tinat members, whilst TIN-2 is associated with the middle-uppermost Tinat Member. TIN-3 is often absent, but comprises a 10-30 ft bed at the top of the Tinat Member. These three chemozones yield elevated Y/U, their differentiation being based on variations in Nb/Th.

Formation and member boundaries were clearly defined using palynological, sedimentological or wireline log trends in the aforementioned reference wells, but this does not hold true in many others. Being sand-prone, the Unayzah Group is normally devoid of palynomorphs and it is

challenging to place such boundaries based on wireline log trends alone. For instance, the lowermost part of the Jawb Member is often indistinguishable from the Ghazal Member. Each member has diagnostic sedimentological features, but these are not visualized in most wells, which are uncored. Consequently, chemostratigraphy is often the only technique that can be utilized to distinguish the members of the Unayzah Group with confidence.

The study concludes that it is possible to apply the scheme on a subregional scale, though minor differences in geochemistry are noted over such a vast area.