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Establishing Volcanic Litho-Stratigraphy in a Tight-Gas Reservoir in Barmer Basin, Rajasthan*

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Abstract

The Raageshwari Deep Gas (RDG) field in the Barmer Basin of Rajasthan, India comprises a tight gas-condensate reservoir within the clastic Fatehgarh Formation and the underlying >1000m thick Volcanic Complex. The Volcanic Complex comprises two major units – upper Prithvi Member (basic lava flows or basalts) and lower Agni Member (stacked silicic pyroclastic flows or felsics interbedded with older basalts). Normal faulting of the RDG rocks has led to formation of a complex network of fractures within the brittle volcanics. These tight reservoirs host approximately 70 per cent of the RDG field Gas-In-Place and vary in thickness and extent across the field owing to variable volcanic emplacement and subsequent erosional controls. Stratigraphic principles established for sedimentary sequences have limited applicability in volcanics, which require an alternative approach. Hence, building a geological concept around a robust stratigraphic correlation is key in order to construct a representative static reservoir model for production history matching and production forecasting.

Introduction

In this poster, we demonstrate how core data and advanced logs (like ECS and image logs) are interpreted and tied with conventional wireline logs in a complex, heterogeneous volcanic rock system to achieve field-wide correlation. These well-based lithostratigraphic tops are further translated to macro-scale by horizon mapping on 3D seismic, wherever the imaging resolution allowed, before being carried forward to the static reservoir model.

Discussion

Presence of locally derived volcano-clastic sediments as observed in core provides insight into the fluvio-lacustrine nature of the Fatehgarh Formation that onlaps onto the Prithvi Member (basalt unit) of the Volcanic Complex on an erosional unconformity (Figure 1a). This erosional control is manifested as extreme variation in Prithvi Member thickness from 0 to >700m across the field making the volcanic litho-stratigraphic correlation and sub-zonation challenging. Compositional analysis of core plugs in the Prithvi Member shows mafic lava flows of trachy-basalt to trachy-andesitic mineralogy (Figure 1b), with typical textural variations from amygdaloidal, porphyritic to brecciated basalt. Emplacement of successive lava flows is generally difficult to demarcate stratigraphically owing to lack of index markers. However, in RDG, wireline log responses and advanced ECS log data has proven presence of diagnostic 'Tuff' markers (or ash beds) within the Prithvi Member (Figure 2a) which, though with limited vertical extent, serve as significant geo-chronological events and guide sub-zonation of stratigraphic packages within the Prithvi Member.

For further sub-zonation, intra-flow variations are considered that impact GR-Res-Dens-Neutron log responses. A typical lava flow profile consists of a dense, massive lava core straddled by more vesicular lava crusts that are prone to hydrothermal alteration and fracturing (Self et al, 1997). While altered flow crusts tend to lower density and increase neutron log values, the alteration minerals themselves may lower resistivity response (zeolite, for example) while increasing GR values. In addition, high-GR basalts have been observed (based on compositional analysis) that indicates a more Basanite-like lithology and hence are characterized as a separate stratigraphic sub-unit.

Results

Within the Agni Member, core study reveals some sub-horizons to be clear interfaces between the interbedded pyroclastic sub-units and older basalts. This is subsequently tied to well log responses and interpreted in all wells across the field. Impedance contrast between basic and acidic sub-units together with the well-picked markers is used for guidance in seismic mapping of the volcanic sub-horizons. The older basalts of Agni Member also indicate a reduced SiO_2 percentage falling within the tephrite/ basanite category of mafic rocks. Further, it is observed from the core data that the felsic rocks of Agni Member are mostly high-alkali trachytes characterized as weakly to strongly welded ignimbrites.

The resultant sub-zonation within the Volcanic Complex (Figure 2b) has helped impart robust structural control in the 3D reservoir model. This ultimately affects reservoir property distribution within the sub-zone framework to better reflect the geological heterogeneity of the reservoir. The correlation scheme may also be tied to well production behavior to better characterize the zone-wise dynamic reservoir parameters during history matching.

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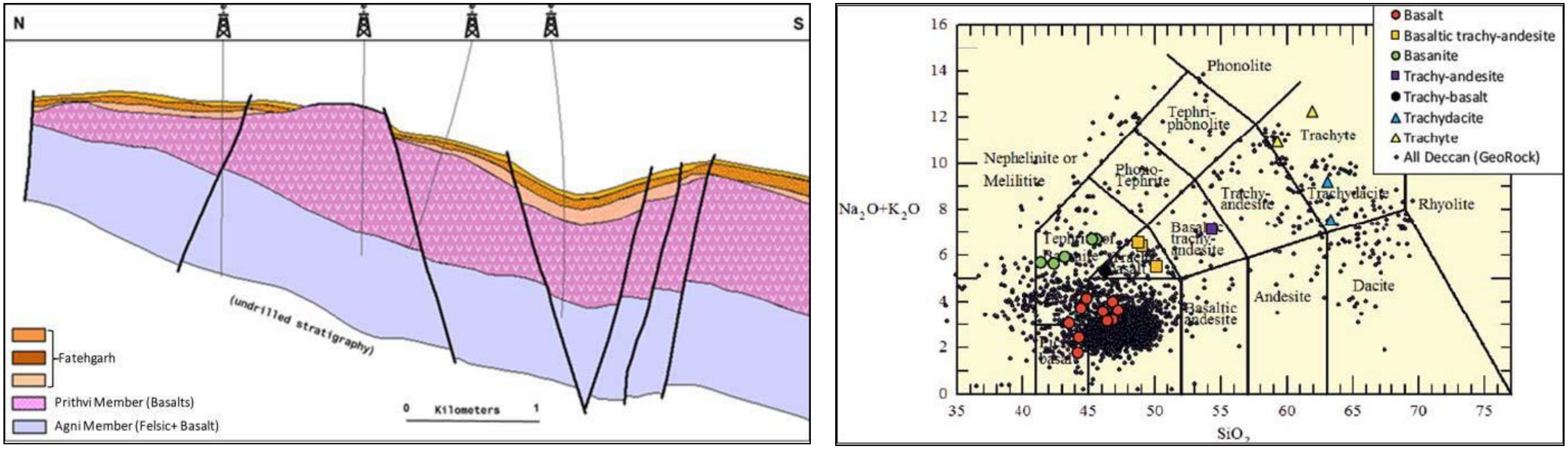
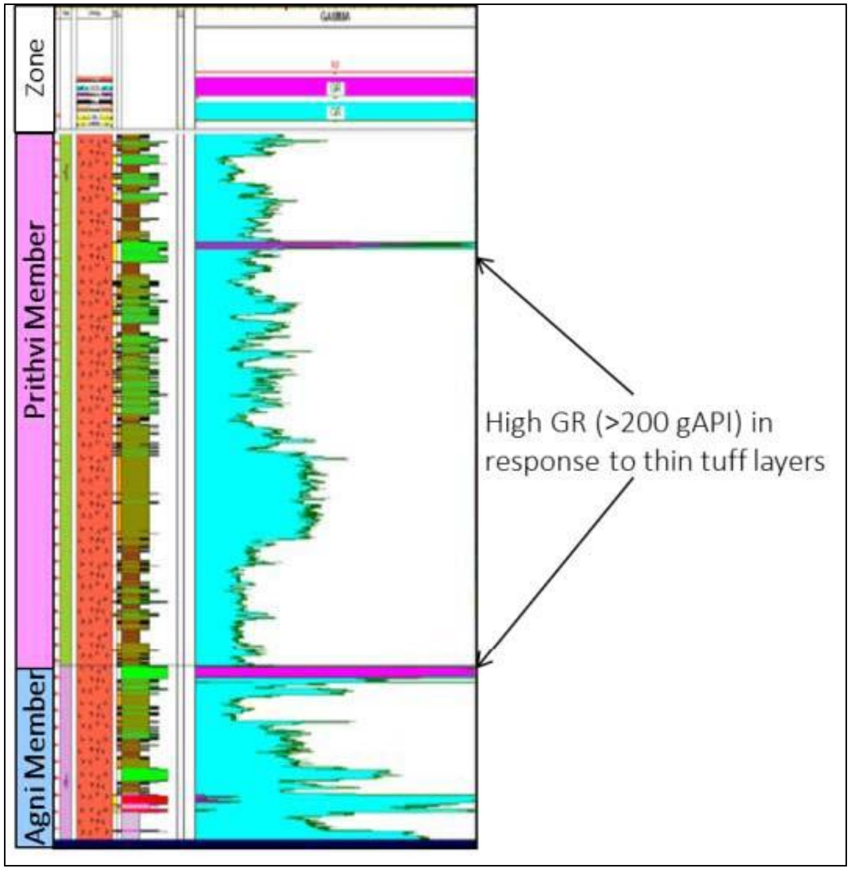


Figure 1. a) Representative stratigraphic section across RDG field depicting the erosional unconformity at base of Fatehgarh that onlaps on the Prithvi Member;

b) TAS diagram showing RDG data as colored points relative to Deccan data in the background (Ref: Georock.org).



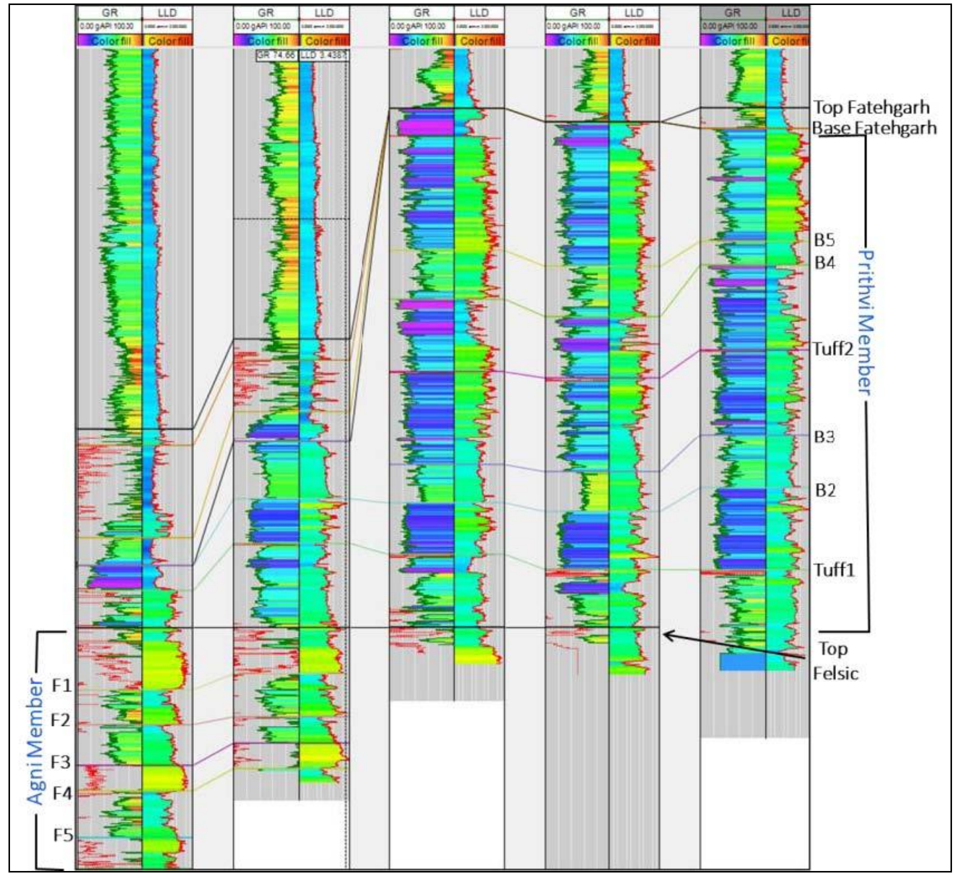


Figure 2. a) ECS log response corresponding to high GR tuff markers (in pink); b) Volcanic sub-zonation within Prithvi and Agni Member.

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