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Surface and Sub-Surface Data Integration in Mouil Graben, Sabalan Geothermal Field, NW Iran

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ABSTRACT

In the collision zone between Arabia and Eurasia, the Plio-Quaternary of the Sabalan volcano, in NW Iran has been identified as a major geothermal field in Iran. A detailed surface and sub-surface exploration program has been carried out in last 20 years. The data related to 11 exploration wells of NWS1 to NWS11 are compiled. Data integration including structural, stratigraphy, alteration and mud loss data indicates that first order structural elements (the caldera-Mouil graben and related faults) and stratigraphy play a major role in the hydrothermal regime. Based on 3D modelling of the main structures combined with mud loss data, it appears that some faults indicate a combined conduit-barrier permeability structure. It is likely that the caldera structure at depths > 1500 m is highly permeable.

1. INTRODUCTION

The post collisional Sabalan strata-volcano erupted in three major phases in last 4.5 million years (Didion and Gemain, 1976; Ghalamghash et al., 2016) and formed on the bedrock of Eocene formations. The stratigraphic units which comprise the cone can be divided into three groups based on surficial outcrops and sub-surficial observations in exploration wells. Given the caldera is the iconic structure in the Sabalan that formed ~0.5-0.3 million years ago (Ghalamghash et al., 2016) we classify the stratigraphic units as follows: 1) Post-Caldera units those are named Dizu and Kasra (SKM, 2005). They include Holocene alluvial terraces and upper Pleistocene lahar and altered magmatic domes. 2) Syn-Caldera units that are named Toas (SKM, 2005). They include middle Pleistocene unaltered trachydacite magmatic domes. 3) Pre-Caldera units which are named Valhazir, Platt and Pliocene Diorite porphyric (SKM, 2005), including lower Pleistocene-Pliocene hydrothermally altered trachyandesitic volcanics and dioritic intrusives. The aforementioned units, except for intrusives, sit unconformably on the highly altered Eocene volcanic rocks (SKM, 2005). A batholitic body of Miocene monzonite intruded at the base of Eocene volcanics and caused contact metamorphism. The main structures including concentric peripheral and radial faults are considered to control the geothermal regime in Sabalan. Caldera ring faults (Figure 1) dip inward and play a major role in transferring the ascending geothermal fluids near the surface. Bounded by the main NW-SE trending Mouil and Dizu normal oblique faults (Figure 1), the Mouil graben, is the most important geothermal prospect in Sabalan that channelizes the heated groundwater downstream where a main cluster of hot springs appears in Sabalan (Rezaei et al., 2019).

2. METHODOLOGY AND DATA ANALYSIS

By compiling structural and stratigraphic data from more than 25 km of drilled sections for 11 exploration wells (SKM, 2005; EDC, 2009) we correlated the data (Figure 2) and produced a stratigraphic section along a NW-SE trend along the Mouil graben (Figure 3). It is indicated where a gradual change in thickness of Post-Caldera units of Dizu is observed. An abrupt increase in thickness in the Pre-Caldera units of Valhazir and a decreasing thickness in the Eocene formation are evident. A major phase of uplift and erosion following an Oligo-Miocene intrusion of mozonite batholite and a Pliocene intrusion of diorite caused the anomalies in the stratigraphic thicknesses. The stratigraphic thickness of the Pre-Caldera units of Valhazir was affected by the location of the caldera.

By investigating the alteration data, we noticed a strong correlation between stratigraphy and alteration in which the Post-Caldera unit of Dizu showed no alteration (Figure 4). The alteration in the Pre-Caldera units is enhanced with stratigraphic age. We also examine the mud loss data to explore a correlation between stratigraphy, alteration and faulting. The impact of the primary permeability due to the stratigraphy is evident in all wells (Figure 5). The Dizu unit showed high mud loss specifically in its contact with the Valhazir unit. By field surveying the main faults including the Mouil graben bounding faults, we constructed a 3D structural model in which the cross cutting of faults with exploration wells was investigated. Mud loss curves have been related to the main faults given the permeability structure of faults. It seems the caldera plays a role as a main conduit for depths >1500 m.

3. CONCLUSION

By supporting field observations, the correlated sub-surface stratigraphy and alteration data indicate a meaningful relationship between alteration and stratigraphy. Mud loss curves combined with the other data indicate that it is highly likely that we were be able to detect the role of the caldera and main faults using the mud loss curves where the wells encounter caldera and fracture zones or cores of the faults.

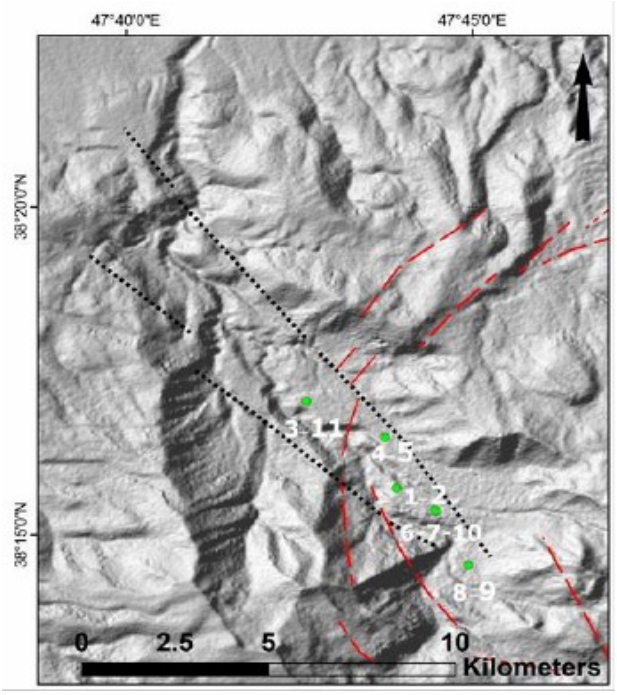

Figure 1: A shaded relief map of the studied area that is overlaid by the first order structural elements: lines (major faults) and points (location of the exploration wells). Red long and black short dotted lines are caldera and Mouil graben bounding faults of Mouil and Dizu, respectively. Green circles indicate the location of the exploration wells (NWS1-11) labelled by numbers in white.

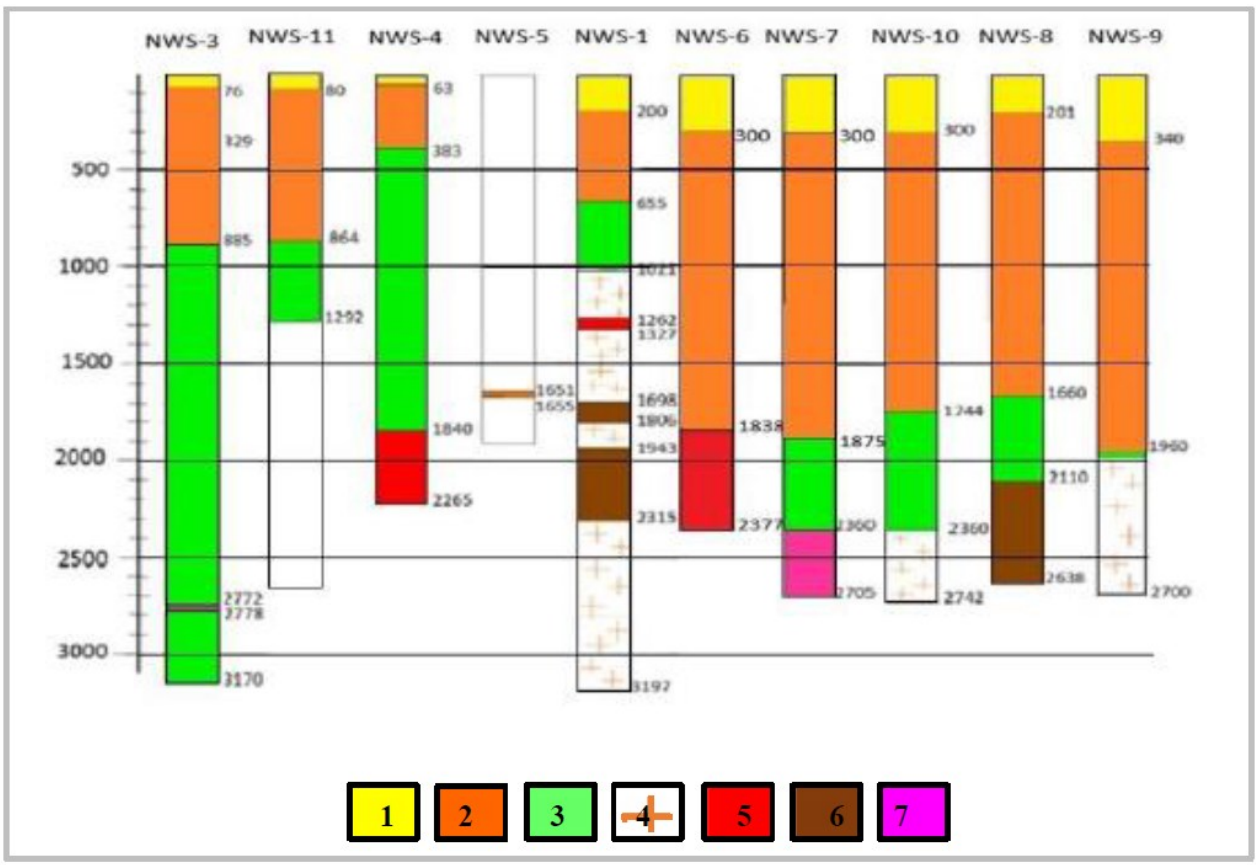

Figure 2: A stratigraphic correlation panel showing the representative well data provided for this study. The presented stratigraphic units are related to the Post-Caldera and the Pre-Caldera. From left to right: 1-Holocene Dizu, 2-Pliocene Valhazir, 3- Eocene, 4- Miocene Monzonite, 5- Pliocene Diorite, 6- Hornfels, 7- old metamorphic rocks. The Syn-Caldera units are absent in this compilation. The white part of the stratigraphy column in wells NWS11 and NWS5 indicate sections that lack data.

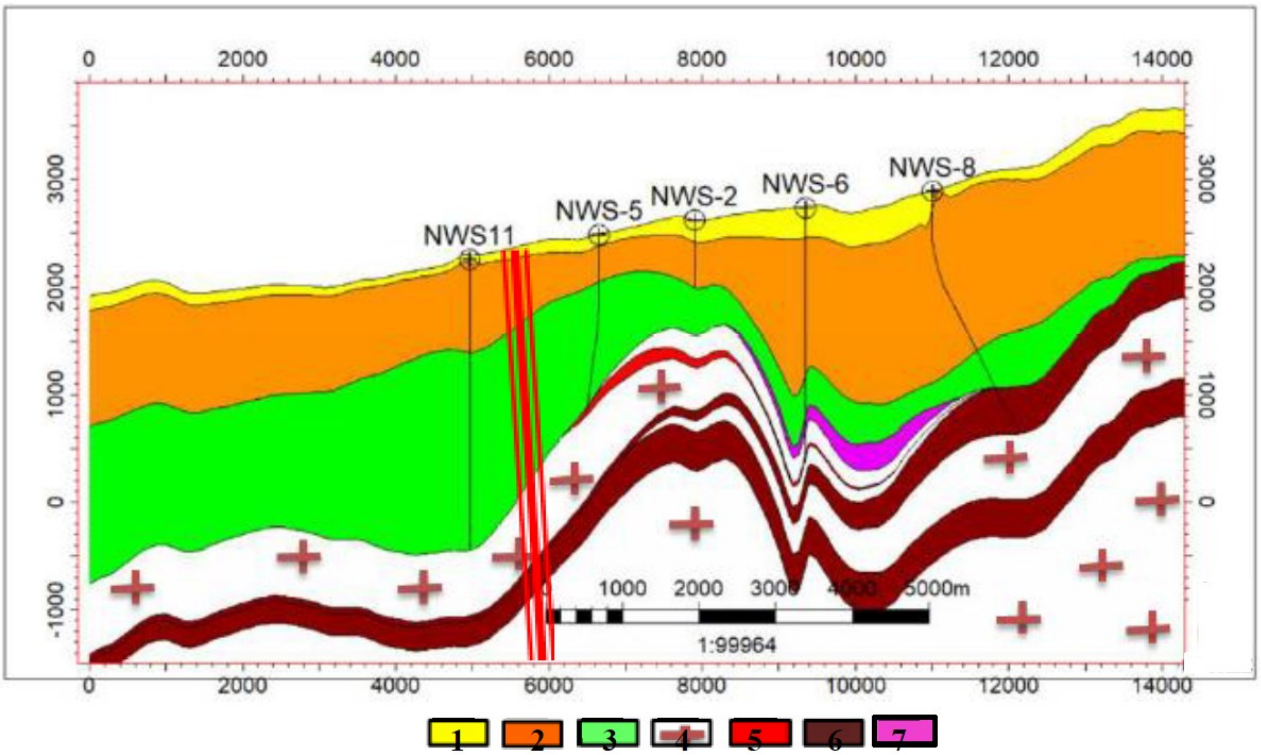

Figure 3: A stratigraphic section which is modeled along the Mouil graben. The data was extracted from exploration well drilling reports (SKM, 2005a-c; EDC, 2009a-f) The presented stratigraphic units are related to the Post-Caldera and the Pre-Caldera. From left to right: 1- Holocene Dizu, 2- Pliocene Valhazir, 3- Eocene, 4- Miocene Monzonite, 5- Pliocene Diorite, 6- Hornfels, 7- old metamorphic rocks. No Syn-Caldera units were surveyed in this section. Caldera rim faults are indicated as multiple red lines. Wells NWS8 and NWS11 are considered in the endpoints of the SE to NW direction, respectively.

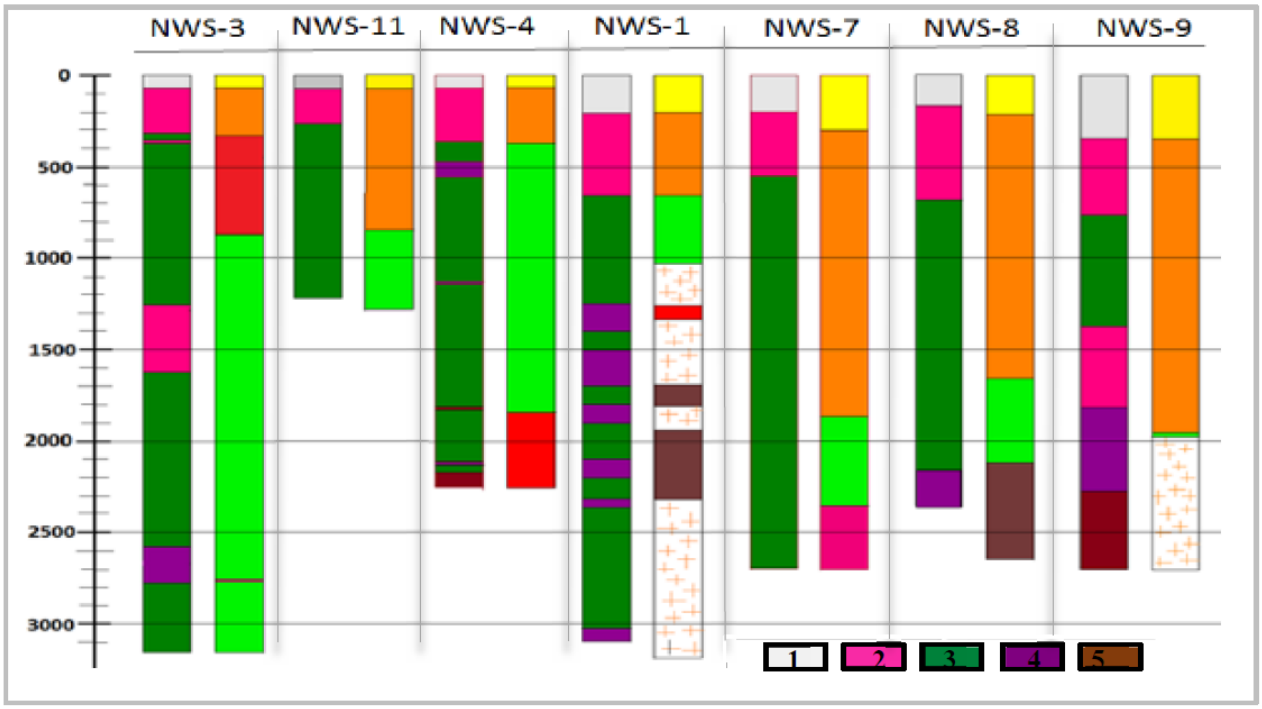

Figure 4: A stratigraphic-alteration correlation panel showing the representative well data provided for this study. The presented stratigraphic units are shown in Figure 2. The presented alterations include argillic, propylitic, phyllic and potassic. They are displayed in the legend by the numbers 1 to 5 from left to right: 1- no alteration corresponding to Holocene Dizu, 2- argillic alteration roughly corresponding to the upper part of Pliocene Valhazir, 3- propylitic, 4- phyllic and 5- potassic.

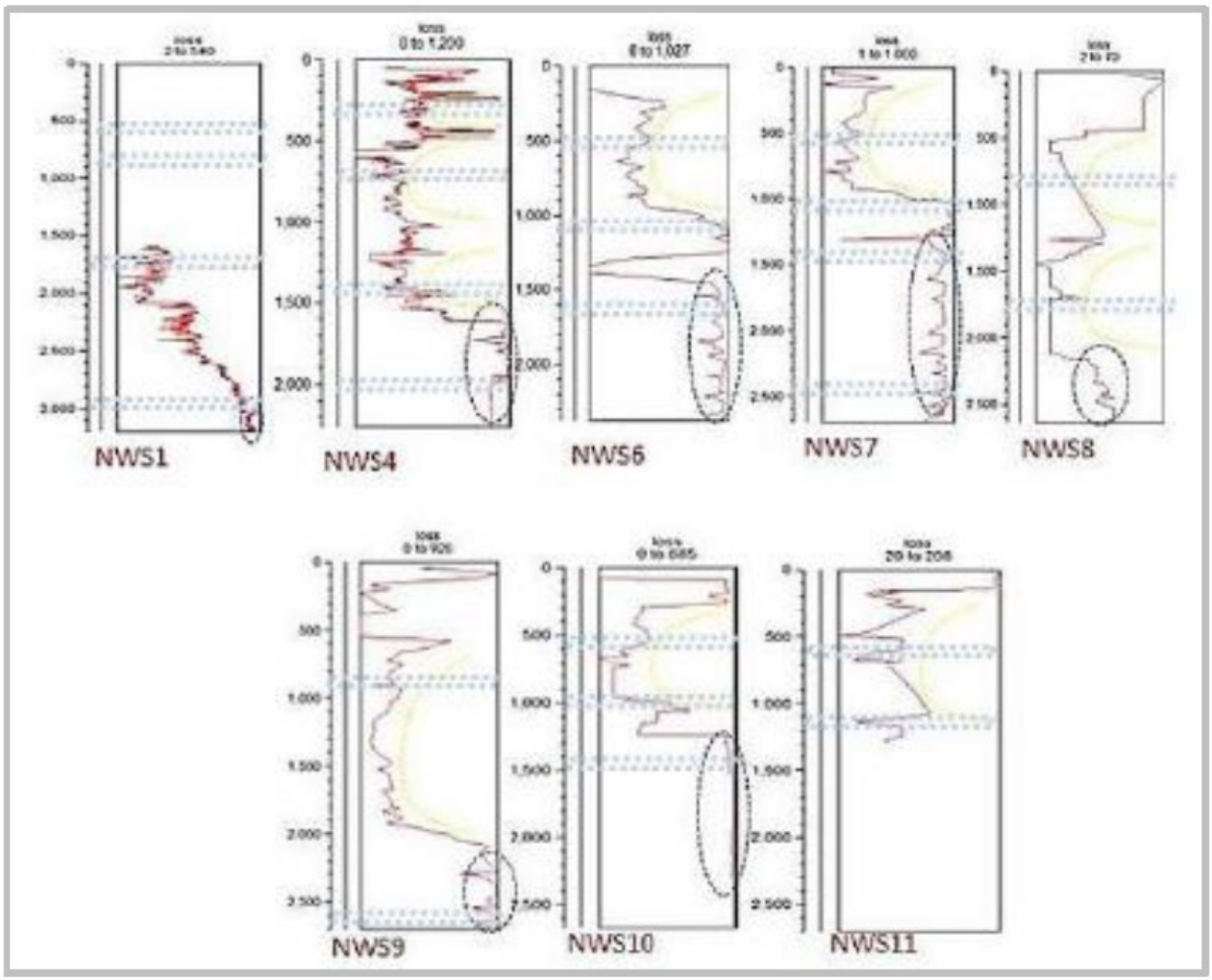

Figure 5: Mud loss data plots with depth that were available from exploration wells. Blue dotted lines correspond to locations where the main faults intersect the wells. The dotted ellipsoids correspond to the caldera.

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