Click to view slide presentation (15 MB)

Examples of Diverse Geomorphology of Petroleum Systems Influenced by Volcanism along Sunda Subduction Trench, Offshore Myanmar*

Naveeparp Paksamut[1] and Suwan Umnuayponwiwat[1]

Search and Discovery Article #30518 (2017)**
Posted October 2, 2017

*Adapted from oral presentation given at 2017 AAPG Asia Pacific Region GTW, Influence of Volcanism and Associated Magmatic Processes on Petroleum Systems, Oamaru, New Zealand, March 14-16, 201

[1]PTTEP, Bangkok, Thailand (NAVEEPARPP@pttep.com)

Abstract

The volcanic arc in the Gulf of Moatama, Myanmar has suspected for years of its hydrocarbon accumulation potential in respective sequence of clastic, carbonate formations and volcanic structures, following an early exploratory drilling by the national oil company in the early ’90. The arc is aligned in the north-south trend along the Sunda subduction trench, where the Indian and Sunda continental plates are collided in the Indian Ocean. Based on early gravity survey, a board overview of volcanoes activities of Sunda subduction trench was noticed. The statistical data of volcano eruption in the region shows in Figure 1. Until a recent exploration and delineation drilling campaign piloted in 2005, drilling result presented a significant petroleum system in relation with volcanism. Different carbonate-volcanic facies were encountered. However, the system is a lot more complex than earlier thought, likely, due to the volcanism and magma processes. It appeared the subsequence of eruption, de-conformation, and diagenesis processes due to intrusion of hot fluid during volcano active period play a key role in petroleum process. The complicity in geo-morphology of the area made the previous exploration unsuccessful, and unlikely to formulate a conceptual development given uncertainty in geological setting. The study is intended to present the process that provides an in-depth evaluation of geo-morphology and qualitative prediction of rock properties.

Terminology and Study Process

With general terminology, three models of volcanism are introduced as 1) Non-explosive, 2) Explosive eruption and 3) Later period of fault movement. The non-explosive eruption model is considered the most important and a preferred condition on a making of fractures and joint set. Explosive eruption, on the other hand, is a destructive event where uppermost part of potential rock is removed. While the remaining cone parts are crushed and if the geological condition is right, might become potential reservoir as well. An interacting of volcanic force against rock formation is critical to the intensity of (open or closed) fracture and joint set in both carbonate and volcanic rocks. We have classified the interaction condition into 3 levels as young, moderate and mature. A young level is an early form of volcanoes by volcanism, where the volcanic force is bending the rock but not exceedingly over rock compressive strength. At this level, primary rock properties are still intact only rock structure is largely bended. In the other words, second porosity is not yet formed and rock layers are still very tight. In a moderate level, volcanic force that exceeding rock compressive strength is applied but not symmetrical to whole rock body: some parts of rocks therefore have no secondary porosity. In the mature level, the whole rock body is totally crushed resulting an extensive fractures and joint set. In addition to volcanic force, it should note that the intensity of fracture or joints is also a function of rock composition and grain sorting. The later period of faults movement can be either destructive or constructive to rock properties but its effect is considered miniscule comparing to the volcano forces. The latter two volcanism models will not be discussed in the study. The step-wise geomorphology analysis is proposed and given in Figure 2.

Some Advices on Seismic Clipping Amplitudes, Spider Random Lines, Reservoir Characterization Using Calibrated Amplitude values as Color Code

During this study, we found a necessity to enhance the quality of seismic data. The clipping amplitude calibrated with the well results is one of suggested process, which its effect on seismic data is not negligible (Figure 3). The enhancement helps improve the quantitative prediction of potential hydrocarbon and corresponding geophysical reservoir characterization.

General seismic in-out lines are found almost impossible to capture a correct geo-morphology that is directly influenced by volcanism. The use of spider seismic random lines provides a better approach in this environment. In collaborating with calibrated amplitude color display, it can effectively capture a full feature of volcanic evolution and magma process. We used various spiral type seismic random lines in the azimuthal attributes for anisotropy vertical transverse isotropy (VTI) which is rotated in 360 degrees and horizontal transverse isotropy (HTI) or time slice. Anisotropy characters are tying with well data to elaborate the stages of volcanism and potential fractured rock interval. By rotation the spider seismic random line section, it can visualize the normal crater or erupted volcano by observing the continuity or discontinuity of layers of carbonate or pyroclastic volcanic on the seismic reflector character. Figure 4 shows the general features of volcano and carbonate platform in study area. Figure 5, Figure 6, and Figure 7 present an arrangement of spider random lines and identify the resulting geomorphology.

Examples of Diverse Geomorphology: WELLS 1-9

WELLS 1-7 (Figure 8, Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13), presents the geomorphology and corresponding well data to explain various levels of rock deformation. The study suggests that volcanism be the primary condition in associated with the joint set and fractures while the fault movement has not or a minor effect. A period of fault movement occurred several times during geological time (Oligocene up to Miocene) while a formation of marine carbonate platform appeared during the volcanism and faults movement in the Andaman Sea. WELL 8 and 9 (Figure 14), the lithology of erupted volcanoes starting from the crater to deeper sequence are very tight, suggests a clear evidence of eruption. For the erupted volcano, we found that the layer of carbonate platform and pyroclastic volcanic are missing (horizon discontinuity) at the crater. Normally, the geomorphology of the normal crater is convex surface but the crater of the erupted volcano is concave.

Some Thoughts on Dip Attributes

Volcanism can create the enormous network of joint set and fractures. In our review, joint set can be detected on the seismic cross section. While fractures can indirectly be visualized by dip attribute values (measuring the values of delta time versus distance), and together with the amplitude values they can provide some measure of quality of reservoirs (carbonate and volcanic). In our study, dip attributes are found to be very effective in detecting the geomorphology with possible fracture network influenced by volcanism comparing to other attributes.

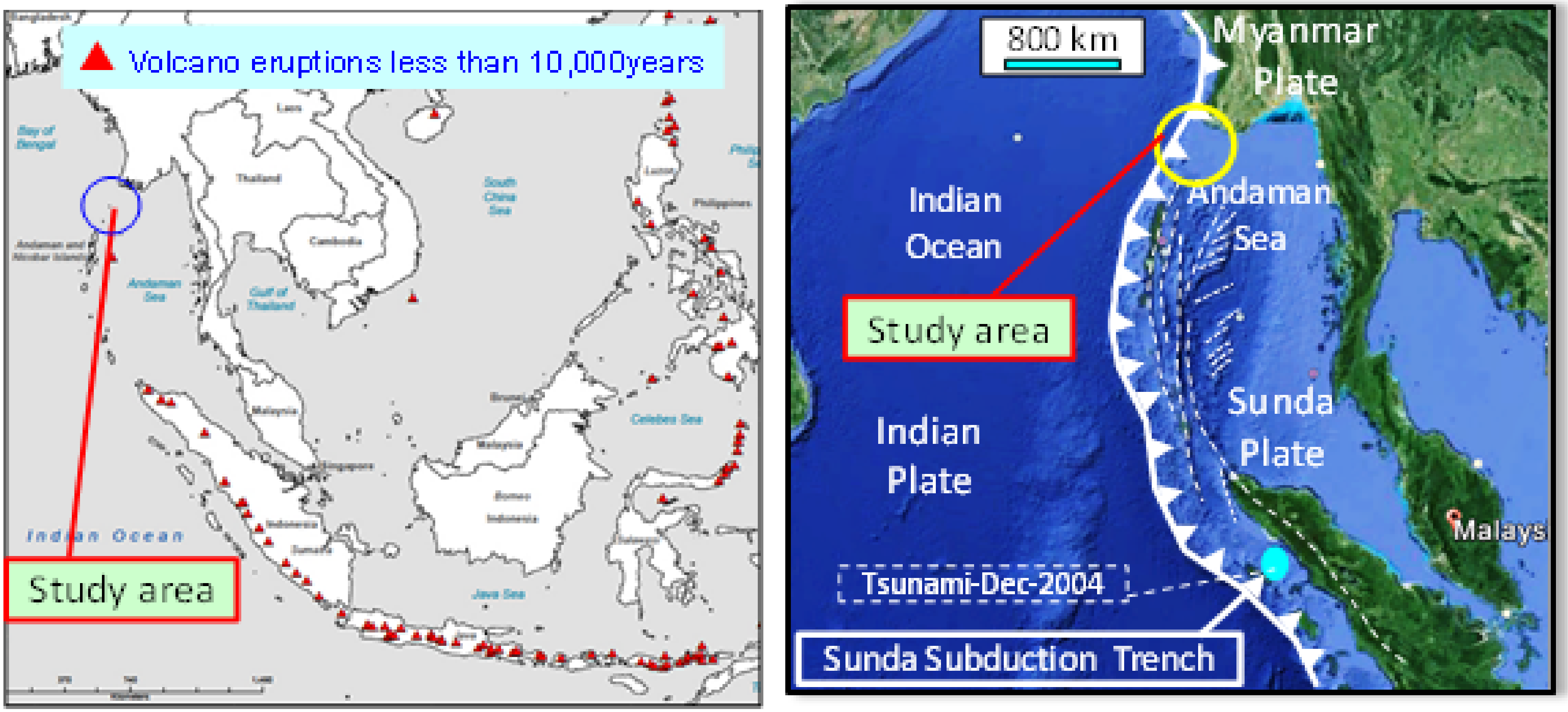

Figure 1. Statistics of Volcano Eruption in the Region and Location of Study Area.

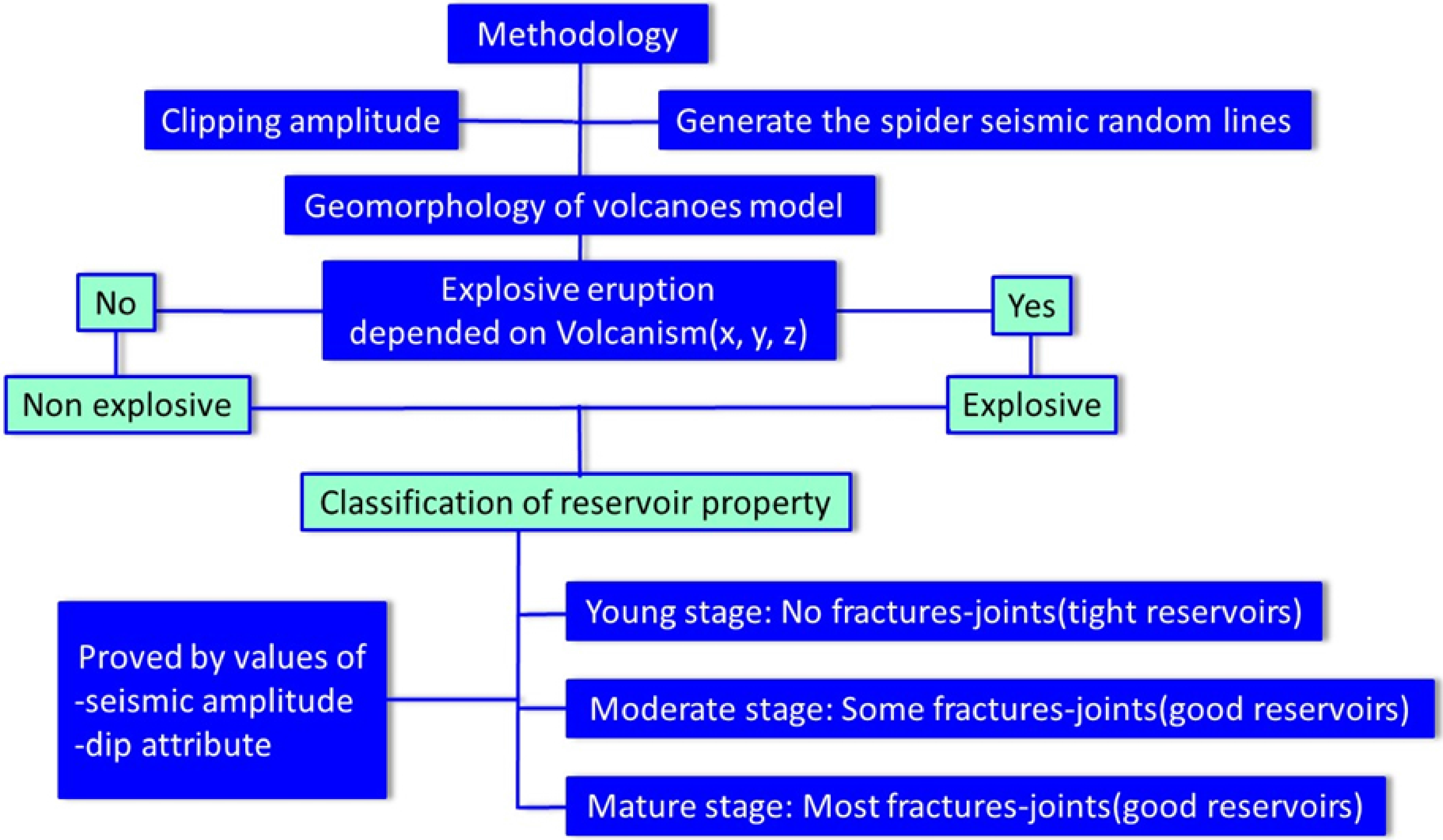

Figure 2. Methodology to Determine Geomorphology and Relating Steps.

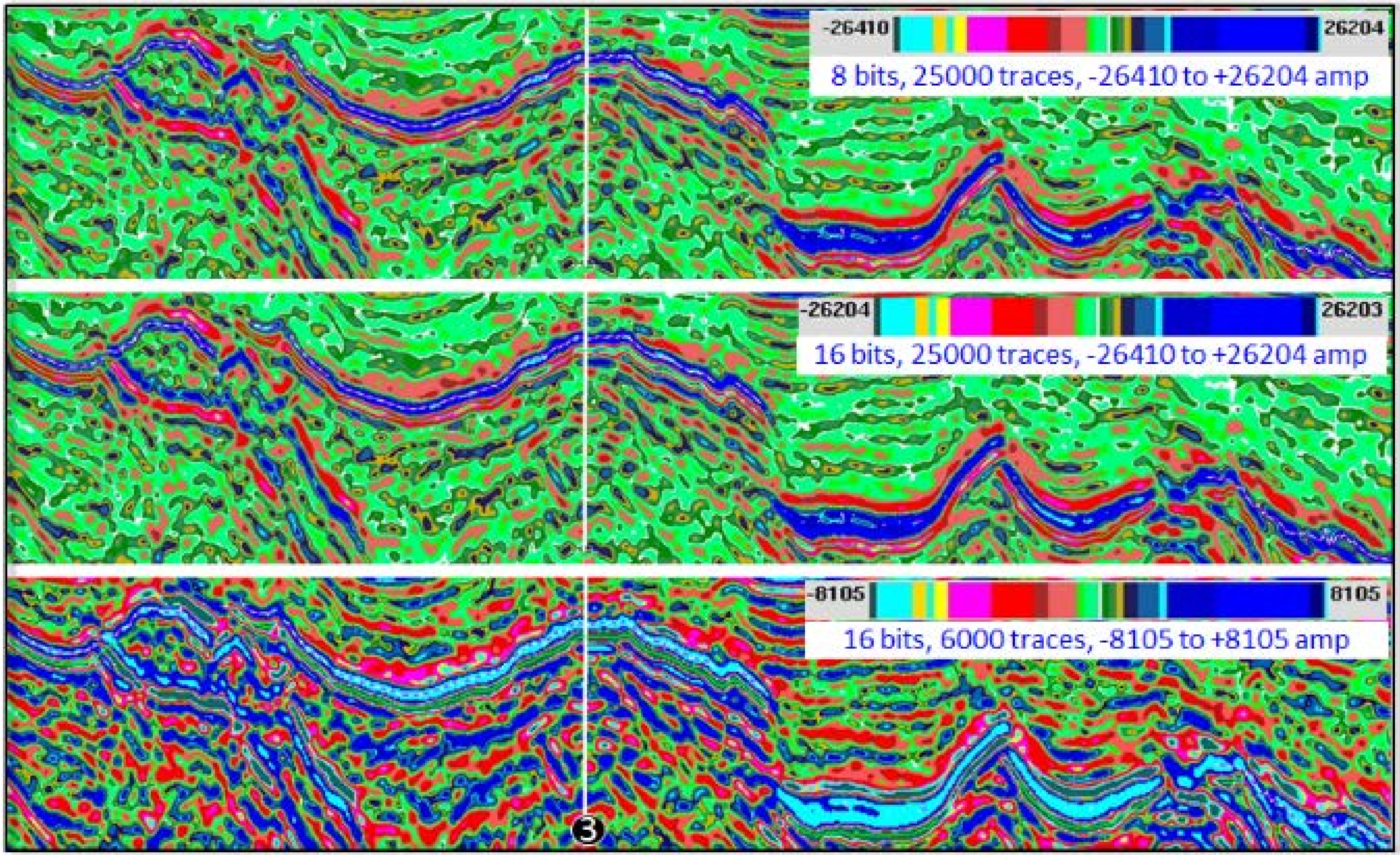

Figure 3. 8 bits, 16 bits, and clipping amplitude.

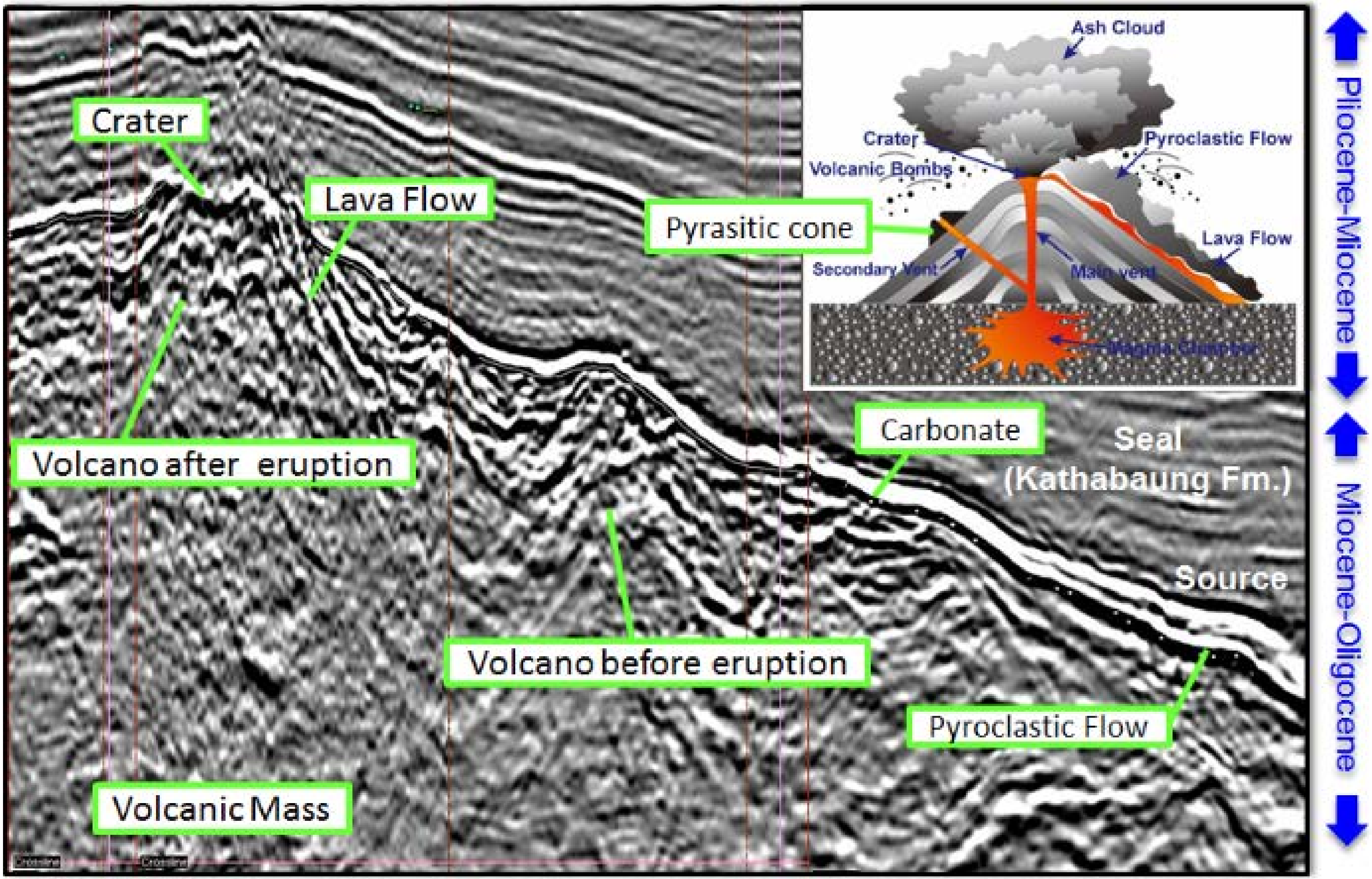

Figure 4. Main Features of Volcano and Carbonate Platform in Myanmar.

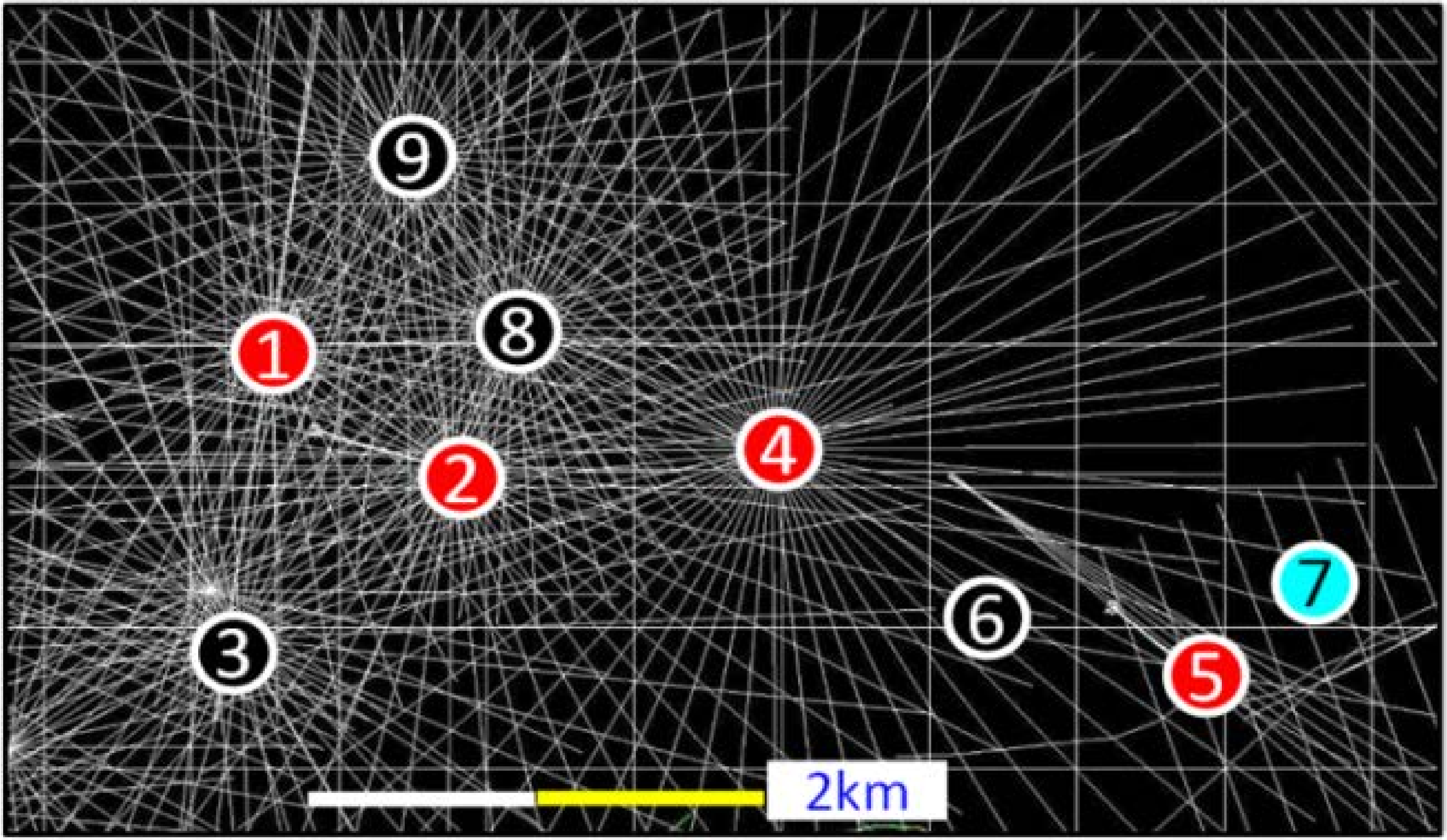

Figure 5. Mapping Geomorphology Using Spider Random Lines.

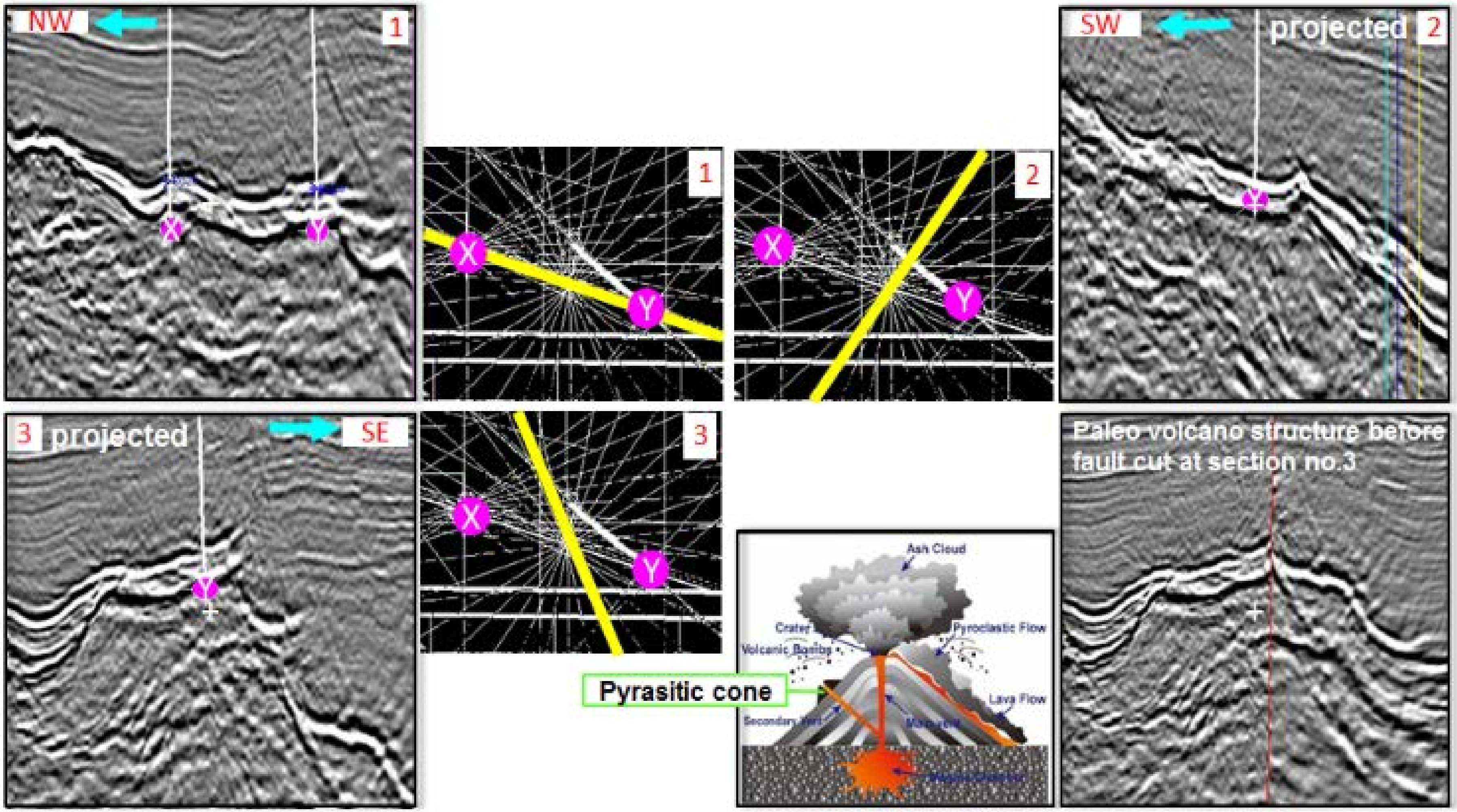

Figure 6. Examples of Geomorphology identification Using Spider Random lines.

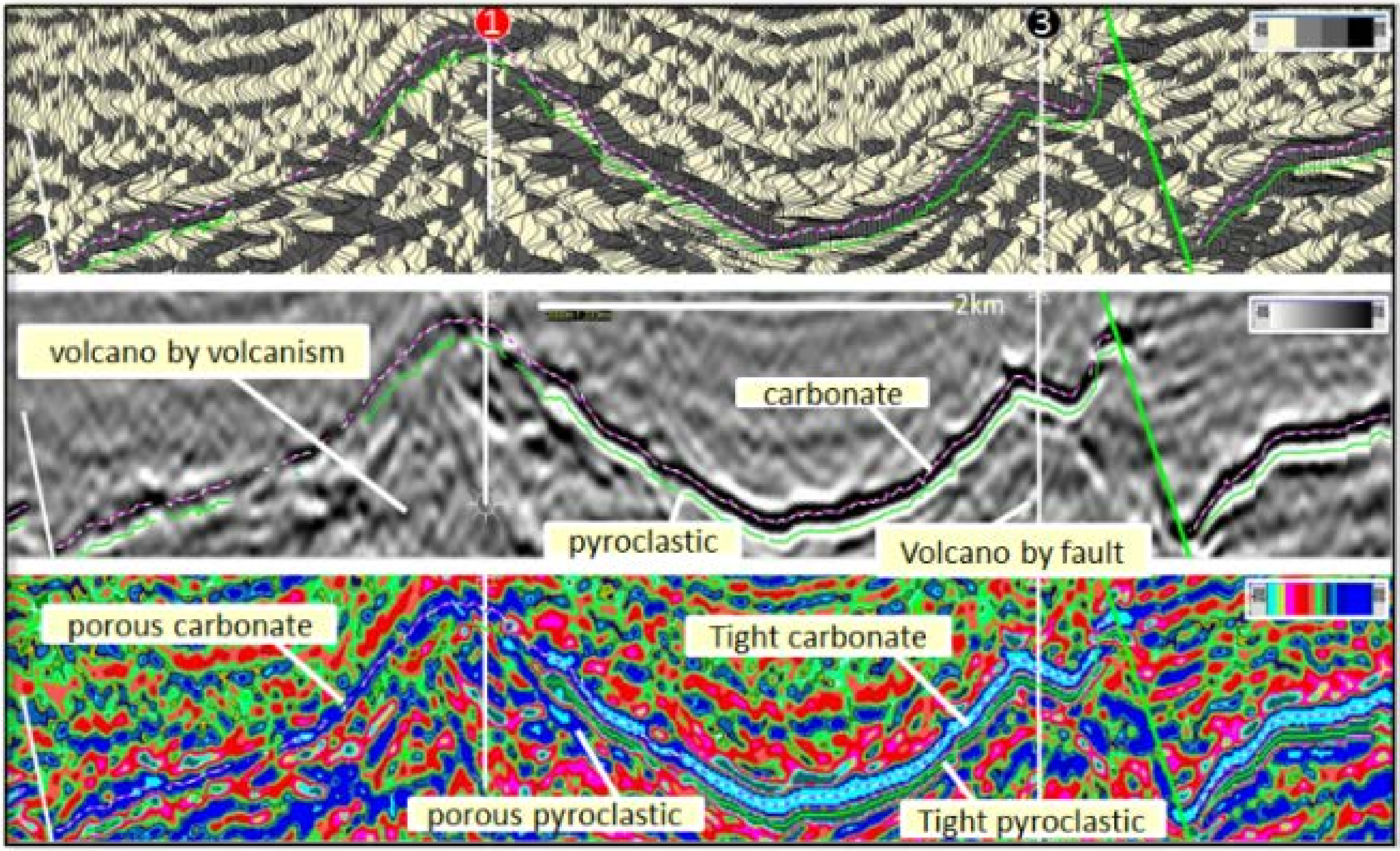

Figure 7. The various seismic displays show carbonate-volcanoes lithology and geomorphology.

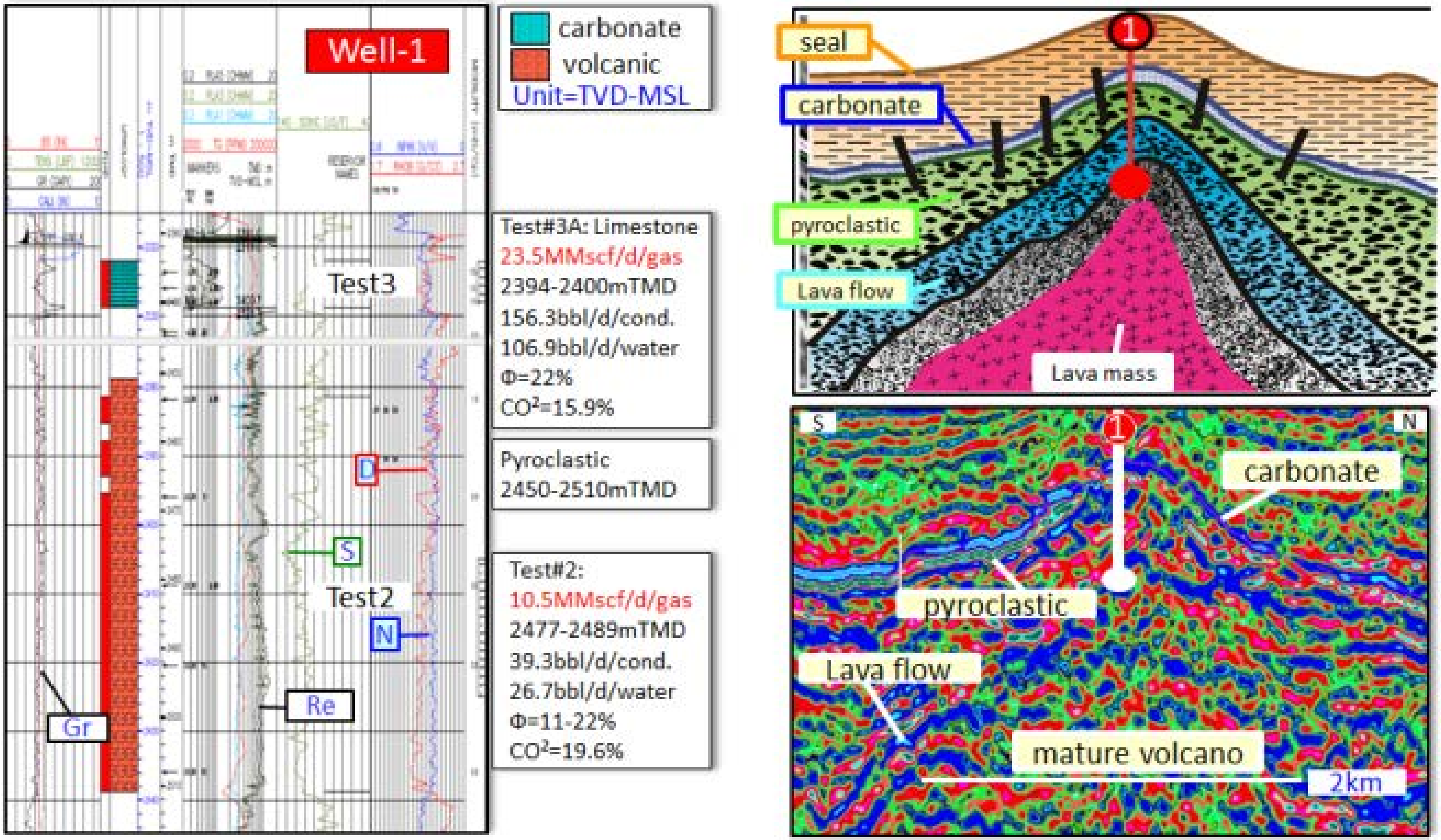

Figure 8. Non-explosive Eruption: WELL-1 showed high productivity observed in both carbonate and pyroclastic sections. Main fractures and joints of volcanic rocks and carbonate platform are affected by volcanism. It is classified as the mature non-explosive volcano.

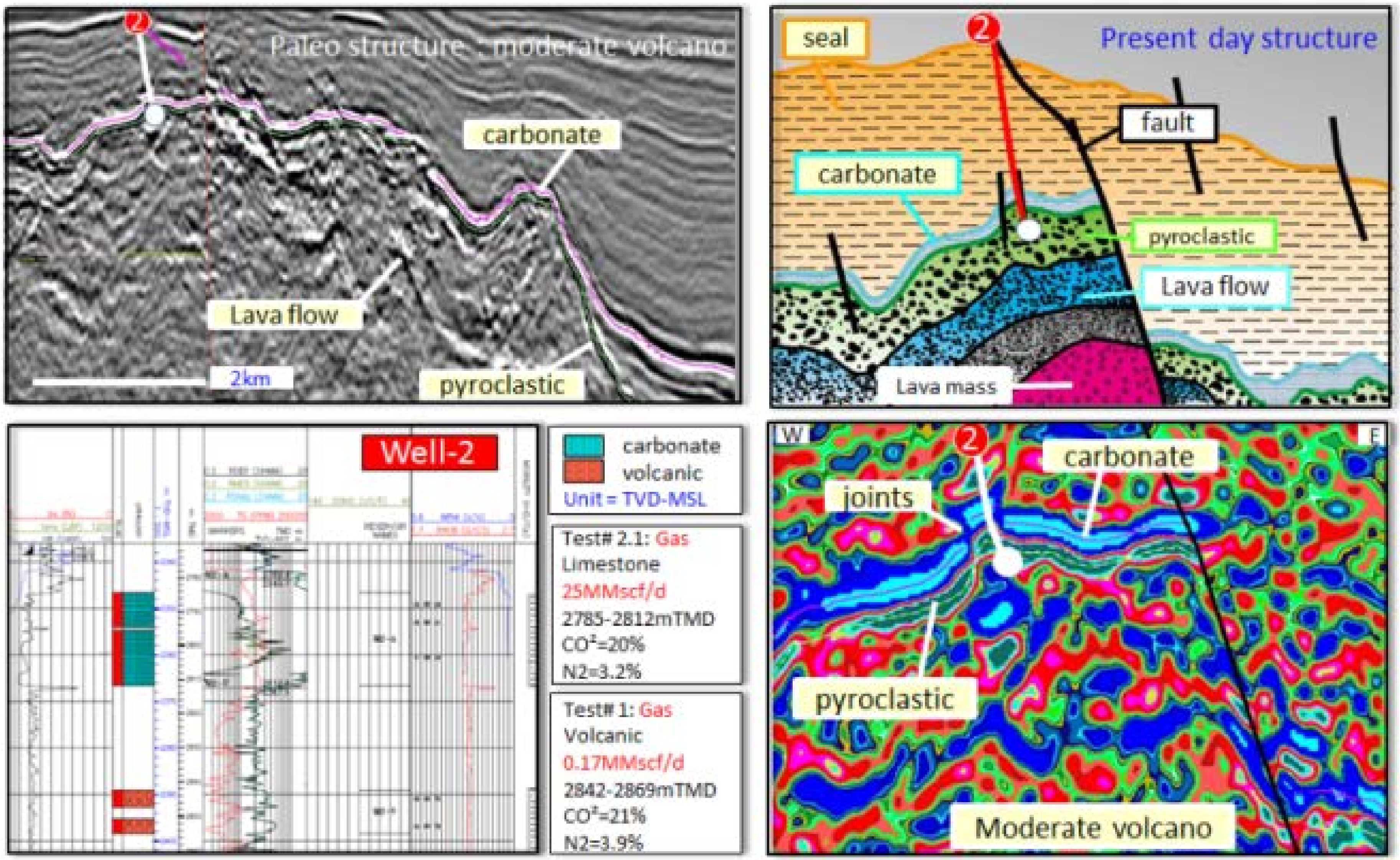

Figure 9. Non-explosive Eruption: WELL-2 also exhibited high productivity. Joints are considered to provide effective secondary porosities for moderate volcano.

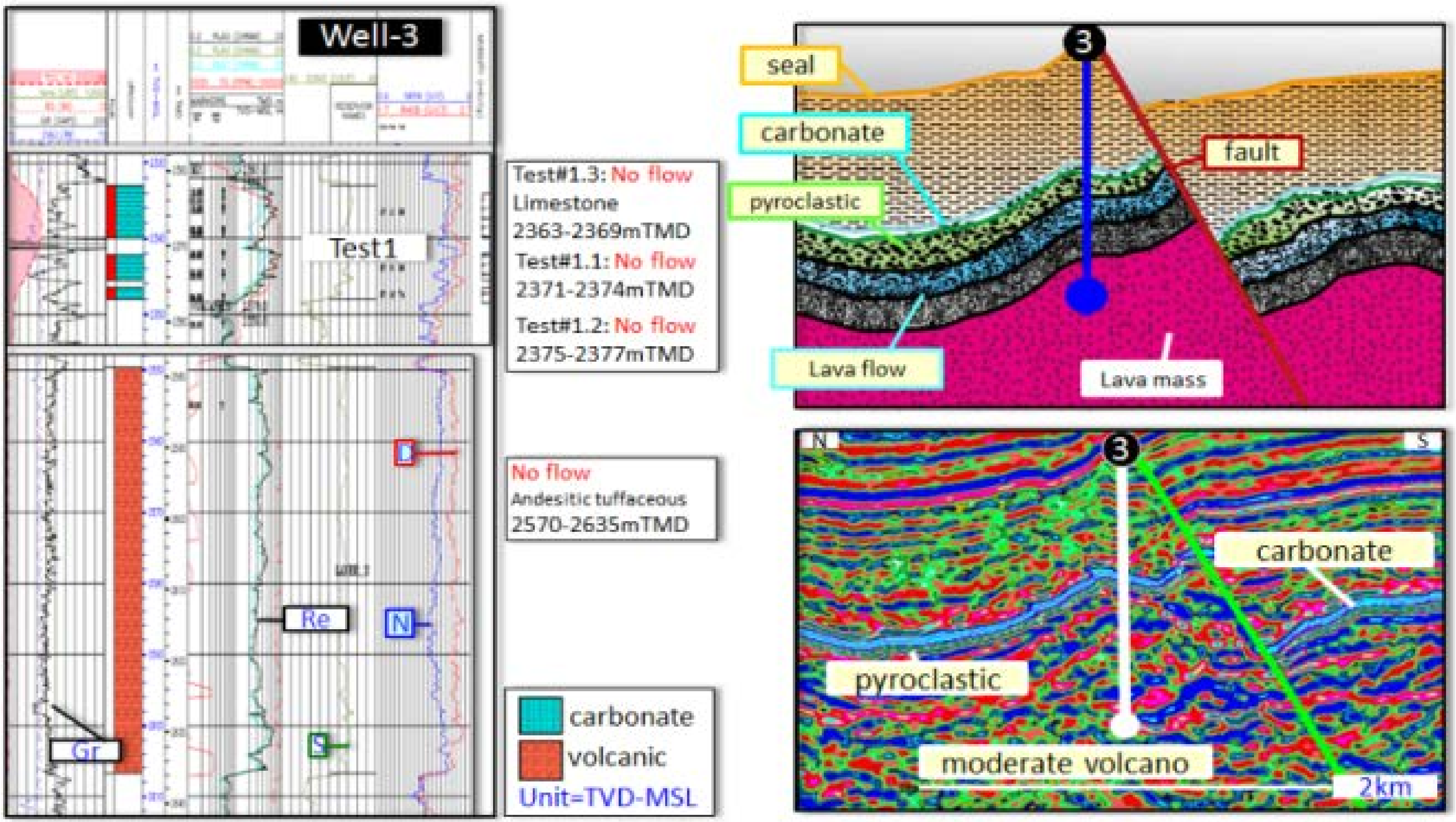

Figure 10. Non-explosive Eruption: WELL-3 was drilled in a moderate non-explosive volcano model with no secondary porosity. In this example, big fault does not improve productivity of carbonate platform and volcanic sections, no flow is observed in both formations.

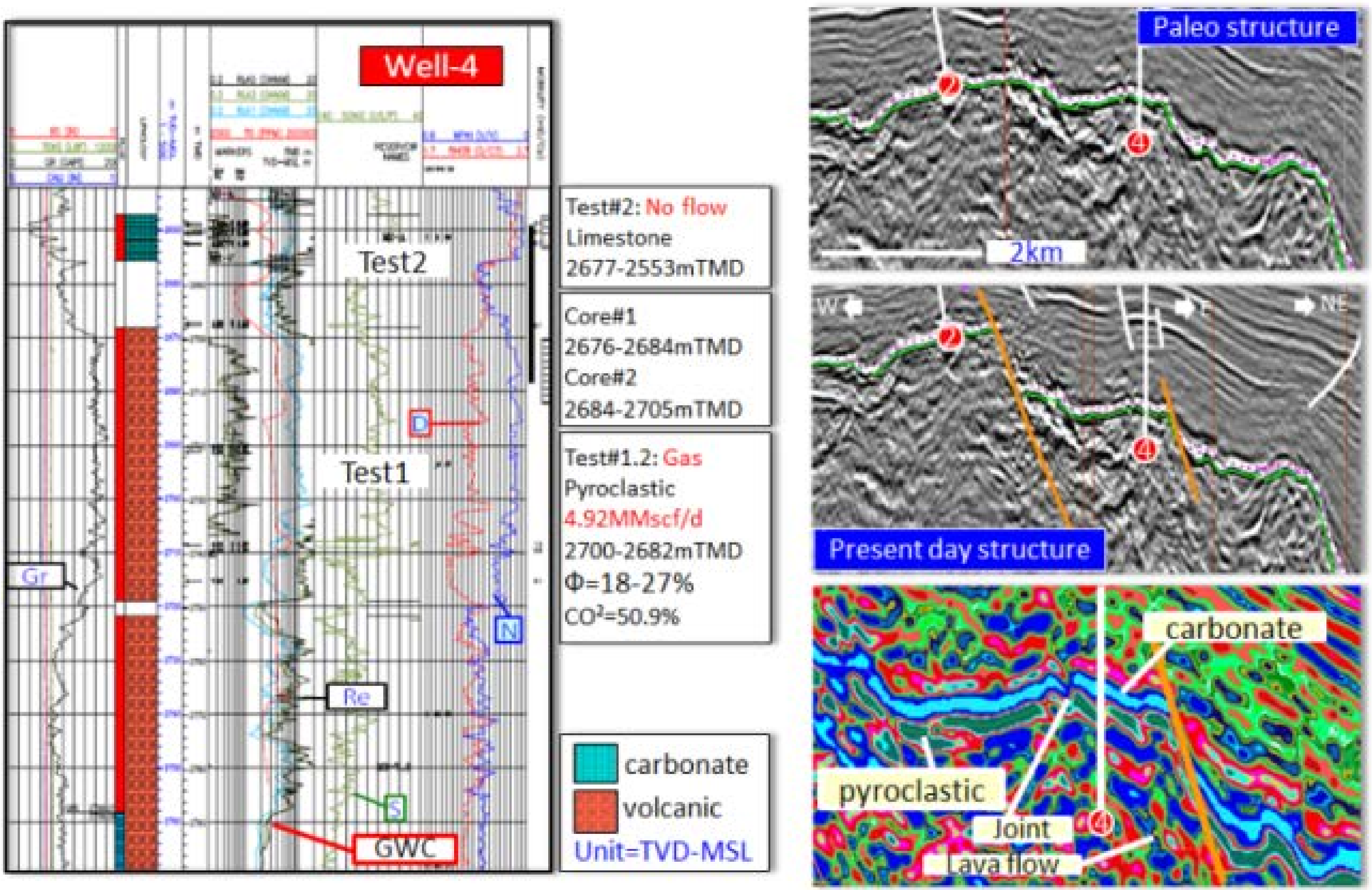

Figure 11. Non-explosive Eruption: WELL 4 penetrated into two rock types (moderate non explosive volcano model) which both rocks have the strongest amplitude value (relate to tight reservoirs) but volcanic has more joint set than carbonate so that only volcanic section produced gas.

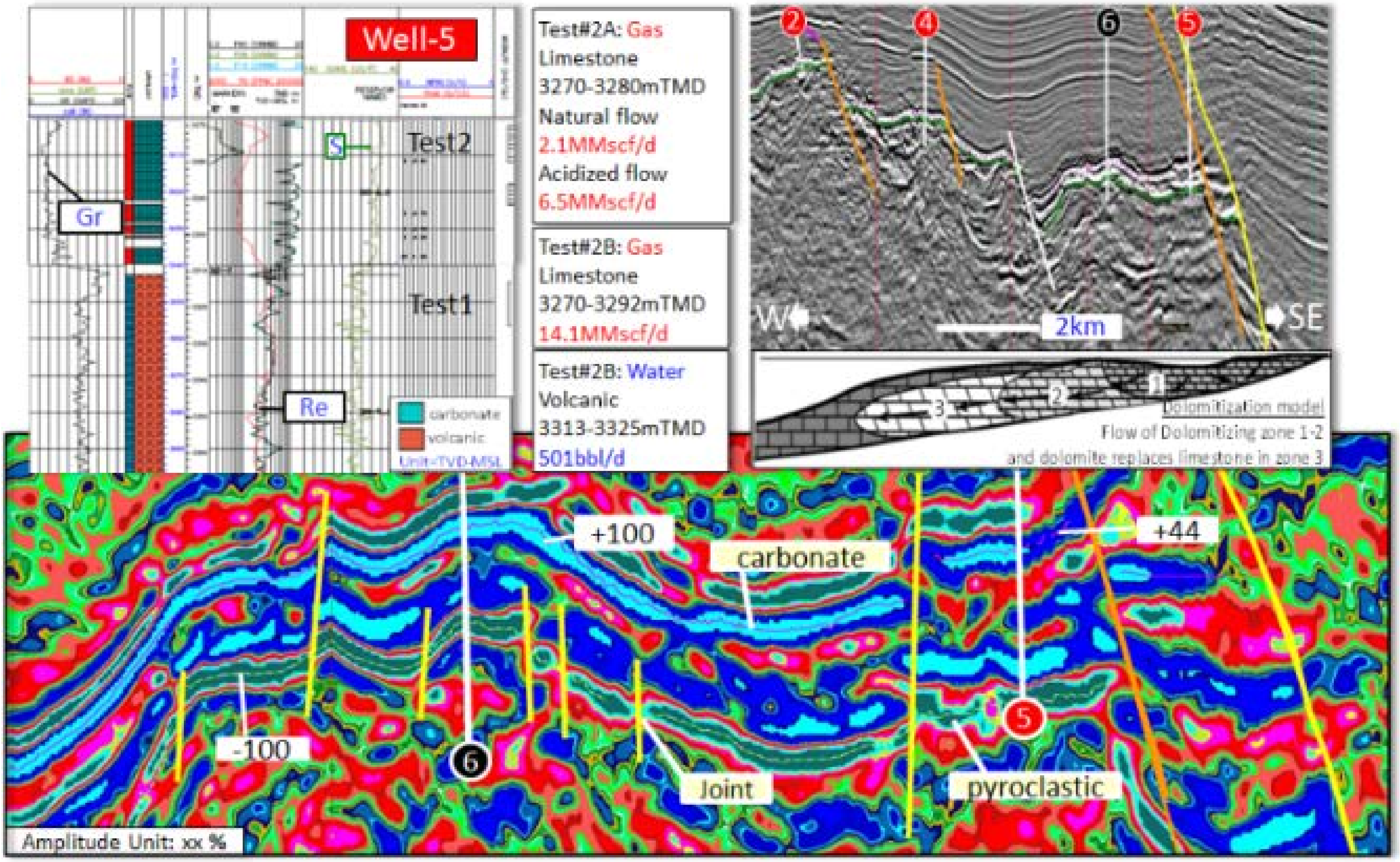

Figure 12. Non-explosive Eruption: WELL 5 and 6 both penetrated into carbonate-volcano sections. WELL 5 observed the dolomitization in carbonate (explicitly display in color palette). Their well test results confirmed better porosity in WELL 5. In pyroclastic rocks, both WELL 5 and 6 penetrated a good moderate non-explosive volcano model with fractures and joint set due to volcanism.

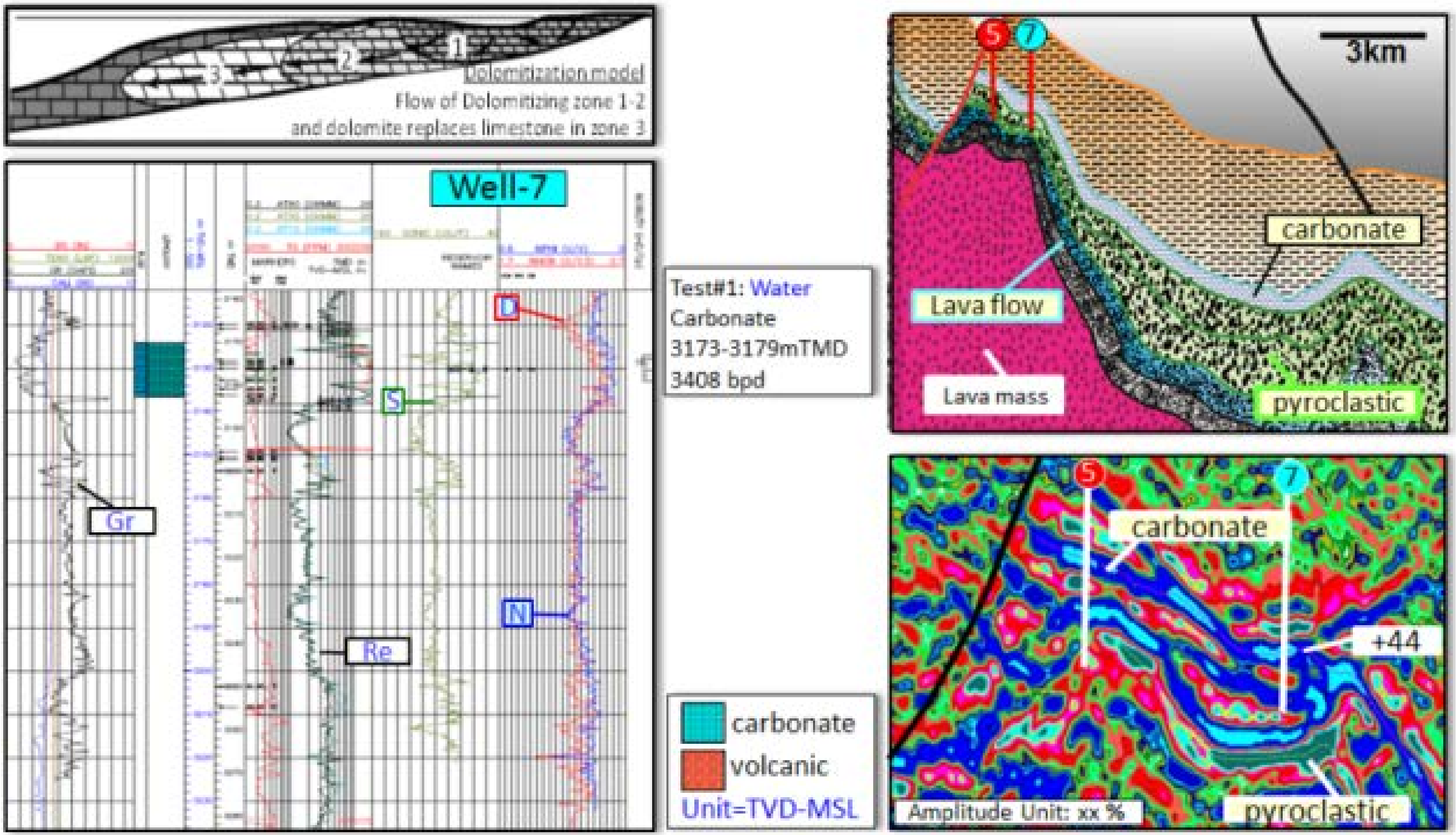

Figure 13. Non-explosive Eruption: WELL 7 drilled a moderate non-explosive volcano model. The lithology of carbonate is alternated and presented a secondary porosity from dolomitization. No joint set observed.

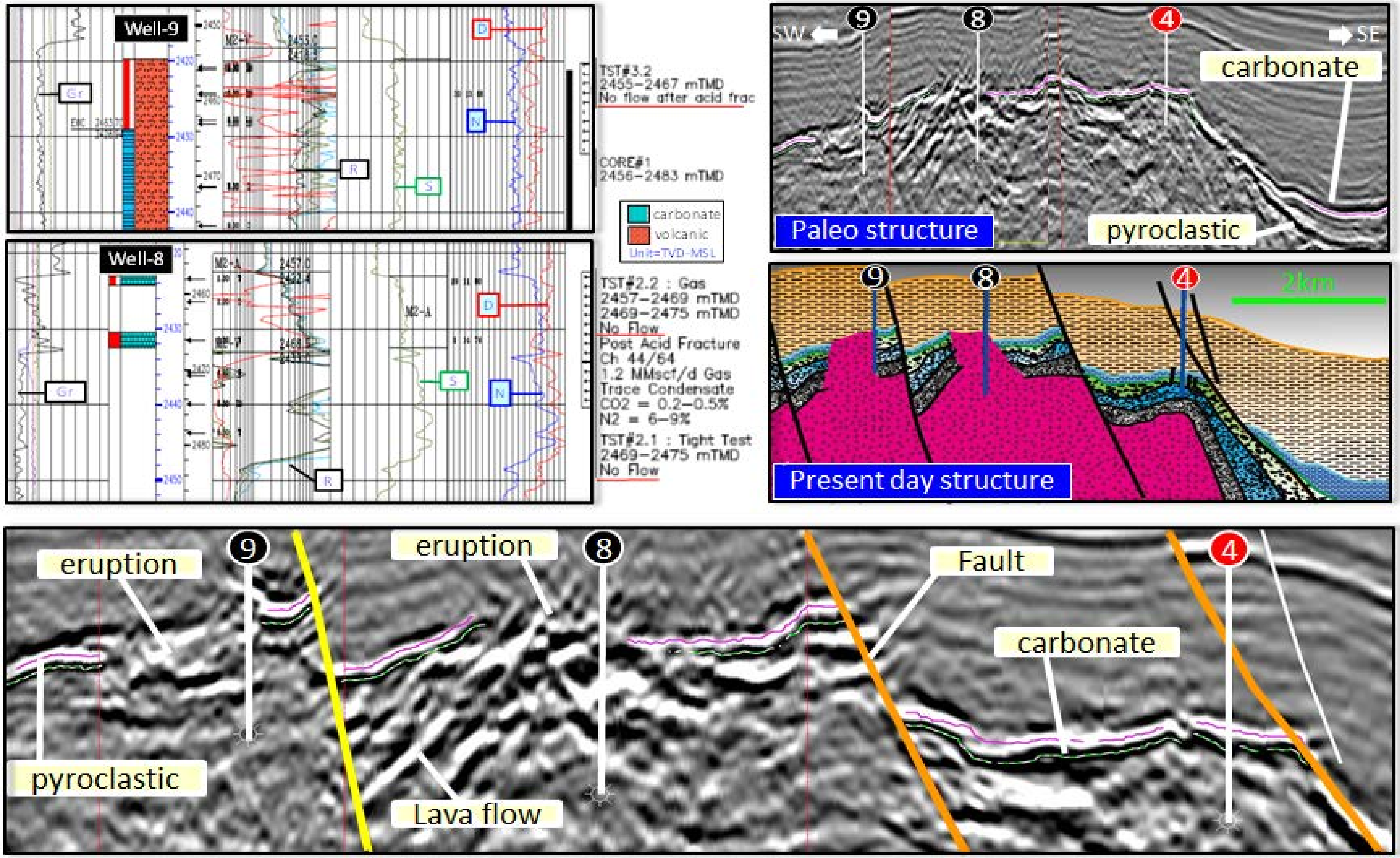

Figure 14. Explosive Eruption: WELL 8 and 9 penetrated the complex explosive eruption model. Massive volcanic rocks from the deeper part were intruded to the surface. Top carbonate and pyroclastic were disappeared. Well tests confirmed very tight section. In this situation, a placement of well to the crushed section of cone, if there exists fractures and joint set, might be critical to development drilling.