Multi-disciplinary Analysis of a Flow Barrier in the Tiwi Geothermal Field, Philippines

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The Tiwi geothermal area is located in the Bicol Peninsula of Southern Luzon Island, on the northeastern flank of Mt. Malinao. After 21 years of production, the Tiwi Geothermal Field has undergone numerous changes and it is now at an advanced stage of development. An update to the current geochemical conceptual model was undertaken in 2001 to refine the understanding fluid flow and reservoir processes This was done both to improve our numerical simulation model and to aid in cost-effective management of the field.

Major structural features separate the Tiwi Geothermal Field into distinct sectors. The pre-exploitation model of the Tiwi resource is that there are two upflow (basal recharge) areas, one in Bariis in the southwestern portion and the other in South Kapipihan (SKap) in south central portion of the field (Fig. 1). The Bariis basal recharge outflows to the northeast, sub-parallel to the Kagumihan Fault. The SKap basal recharge outflows towards the northeast, sub-parallel to the Tiwi Fault. This latter outflow is associated with major thermal manifestations in the Naglagbong Park (Nag Park). This outflow process was reversed after production started in 1979, as reservoir pressures declined

Review of geochemical, reservoir engineering and geophysical data provides strong evidence that the Tiwi Fault is the most likely barrier that separates the low-pressure (NW of Tiwi Fault) and high-pressure (SE of Tiwi Fault) groups of wells in SKap portion of the Tiwi Geothermal Field. These two groups have distinct initial-state chemical characteristics that support this theory. Historical gravity responses and pressure responses in wells near the fault also confirm this separation.

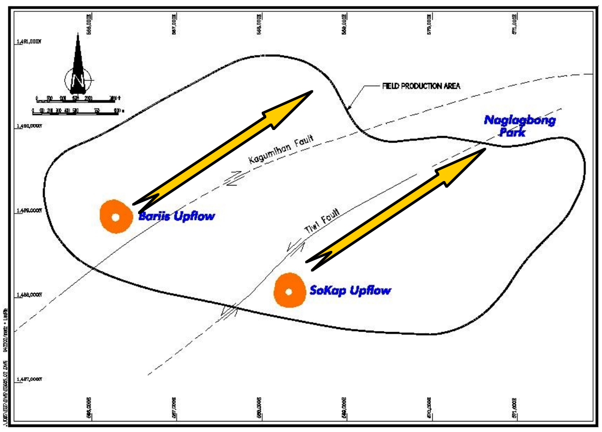

Fig. 1: Map of Tiwi Field that locates field outline, two major upflows/outflows and two major structures.

Contrasting mantle sources for the Permian mafic magmatism in the Alps: insight from the Mont-Collon gabbro (Dent-Blanche nappe, western Alps)

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In Early Permian, many mafic complexes (=PMCs) intruded within the future Austroalpine and Southern Alpine domains (e.g. Anzasca, Malenco, Ivrea, Sondalo). These occurrences, which must be distinguished from gabbros of the Jurassic Tethyan rifting, evidence a major melting episode of the mantle ascribed to the post-orogenic thinning of the Variscan lithosphere. The Mont Collon mafic complex is one of the best preserved example of this Permian tholeiitic magmatism in the Central Alps. It mostly consists of olivine to cpx-bearing gabbros, with cumulitic structures, crosscut by acidic and mafic dykes. IDTIMS U-Pb zircon ages of 284.2 ± 0.7 and 282.93 ± 0.59 Ma were obtained on a pegmatitic gabbro and a tonalitic dyke, respectively. These magmatic ages are very similar to those of the other PMCs.

Post-orogenic extension of the European Variscan belt is thought to be induced by the roll-back effect of the still subducting Paleotethys oceanic slab on the eastern side of the belt. Melting of the mantle might have been initiated by decompression and/or lithospheric delamination. Magmas can thus originate either from the lithosphere or from the underlying asthenosphere. Associated acidic melts were generated by the partial fusion of the lower crust ($\varepsilon Nd_{(283)} = -7.82$), induced by the heat input from the mafic magmas.

Gabbros are Ol+Hy-normative. They are not representative of liquids and their trace-element composition reveals a cumulative character (e.g. positive Eu anomaly), low La/Yb_N of 1.9 to 4.5 and $\Sigma REE_N \sim 95$, rather constant Mg# between 60 to 69, a strong negative Nb-Ta anomaly and $\varepsilon Nd_{(284)}$ between –0.20 and +2.8. The rare liquid representatives are very contrasting. These are high-Fe-Ti tholeiitic basic dykes, displaying enriched patterns ($La/Yb_N > 13$, $\Sigma REE_N \sim 700$), a positive Nb-Ta anomaly and a $\varepsilon Nd_{(283)}$ of +7.15, all reminiscent of OIB-type rocks. The systematic negative Nb-Ta anomaly of the gabbros and their uniform Mg# might reflect a wet (subcontinental?) mantle source and/or crustal contamination, whereas the enriched tholeiitic Fe-Ti dykes rather point to an asthenospheric origin.

Ongoing Pb isotopic work and LA-ICP-MS trace-element analysis on cumulative cpx and subsequent modelling of melt composition should allow a better characterisation of the mantle sources.