HYDROTHERMAL ALTERATION IN 410 AND 506-D, TONGONAN GEOTHERMAL FIELD, LEYTE, PHILIPPINES

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ABSTRACT

Geology and hydrothermal alteration of the Tongonan geothermal field, Leyte, Philippines are summarized. This is followed by petrologic descriptions of the mineralogy from two deep wells, 506-D in the Malitbog sector and 410 in the Mahiao sector.

Petrographic techniques were used to analyse cuttings and cores from the two drillholes. Identification of the mineralogy was through examination of hand specimens and thirty-five thin sections of core and cuttings. Fluid inclusion temperatures were measured from core in 506-D at 2648 m (MD). Information gained from these techniques has been correlated and used to interpret lithology, mineralogy, hydrothermal alteration and temperatures encountered in these two wells.

INTRODUCTION

Earliest shallow exploration wells (≈600 m) in the Bao River valley, southwest of Malitbog were sited on the basis of surface geology and surface geothermal manifestations. (TGE Figure 1). Results obtained from drilling in the Bao Springs area were not encouraging and interest shifted north to the Mahiao valley whose hot springs, together with an area of relatively low apparent resistivity suggested the existence of a geothermal reservoir. A further shallow well, TGE 10 was drilled, the results of which were sufficiently promising to justify drilling of the first deep well, 401. Following successful deep drilling in the Mahiao/Sambaloran sector attention focused on testing the extension of the Mahiao resistivity anomaly into the south Sambaloran and upper Malitbog valley areas. Currently some fifty deep wells have been drilled in the Tongonan Field as part of a programme to provide electrical power for the island.

Stratigraphy

The lithologies encountered in both the Malitbog and Mahiao/Sambaloran sectors are similar. (Figure 2) The Bao volcanics which are the thickest sequence encountered during drilling comprise fresh to propylitized hornblende andesites with minor tuffs, breccias, pyroxene and biotite andesites. This lithology is typically intersected from surface to -1500 m RSL in the Malitbog and Mahiao areas.

The Sambaloran Formation, a sedimentary sequence of some 50 m to 100 m within the Bao Volcanics contains limestone, carbonaceous sandstones and siltstones. This facies was probably formed in a part-terrestrial part-marine shallow lagoonal environment, and may represent a hiatus during an otherwise continuous eruptive phase which deposited the Bao Volcanics. As the name suggests this formation is typical of the Mahiao/Sambaloran sector, thinning to the southeast in the Malitbog sector.

A contact zone underlying the Bao Volcanics contains propylitized andesites and andesite/microdiorite breccias. Its thickness varies considerably across the field (Figure 3). It frequently coincides with a production zone and grades into the Mahiao Plutonic Complex with depth.

The plutonic complex comprises fine grained microdiorite which grades into a coarse grained quartz diorite. The intrusive is intersected at shallower levels in the Mahiao/Sambaloran sector than in the Malitbog.

Late stage intrusive dacite dykes are encountered mostly within the contact zone. A steeply dipping clinopyroxene dyke is intersected in 403, 409, 405 and 515D.

Figure 1: Tongonan Field, Leyte, Philippines.

Hydrothermal Alteration in the Malitbog Sector

The Tongonan Field is characterized by mineral assemblages of recent and relict alteration. In general the hydrothermal mineral assemblages within the Upper Mahiao area are in the equilibrium with present day geothermal fluids whereas within the Malitbog sector high temperature assemblages are considered relict since they are not in equilibrium with lower temperatures recorded from present-day downhole testing. Four zones of hydrothermal alteration are present in the Malitbog field as described by Leach and Bogie for the Okoy Field (1982).

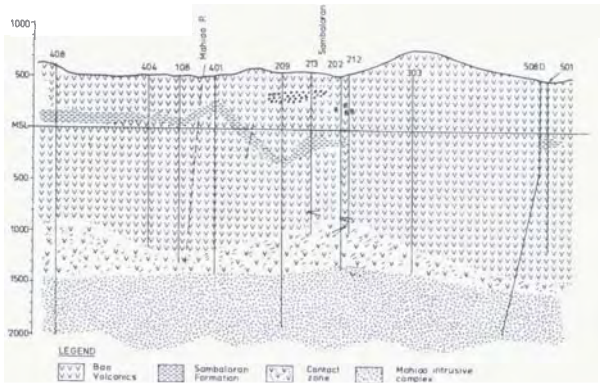

Figure 2: Generalized Geological Cross-Section Tongonan (section line shown on Fig. 1 C-C')

(a) Propylitic
(b) Potassic
(c) Advanced argillic
(d) Low grade hydrothermal alteration

(a) The most extensive zone is a propylitic zone characterized by epidote and encountered in Malitbog wells. Accessory minerals include albite, chlorite, anhydrite, pyrite and calcite. Epidote is thought to be indicative of temperatures in excess of 250°C. The evidence is somewhat equivocal as to the recent or fossil origin of the epidote assemblage in the Malitbog.

Relict propylitic alteration has been observed in the upper levels of Malitbog wells 505, 507, 508, 510, 511 and 515. Epidote has been observed as high as -200 m RSL in 510. Similar mineral assemblages throughout the wells may also be a continuation of the high temperature relict system. However, where current downhole temperatures and mineralogy temperatures are similar, it is not possible to know whether mineral assemblages are relict or recent.

(b) A relict potassic zone characterized by biotite and magnetite indicative of formation temperatures in excess of 325°C, is encountered in Malitbog wells 502, 503, 505-D, 506-D, 5R7-D, 509, 510-D and 511-D. The absence of the relict potassic zone in 508-D, 515-D, 509 and 5R4 suggests a lower maximum temperature of the relict hydrothermal system towards the south-west. Relict biotite is also observed in hot Upper Mahiao wells 403 and 408.

(c) An advanced argillic zone containing diaspore and/or pyrophyllite is present in Mahiao wells 401, 403, 407, 408 and 409 and in Malitbog wells 501, 503, 5R7-D, 509, 510-D and 515-D. This zone in the Malitbog is considered relict because acidic fluids are not evidenced in the present day field.

(d) A low grade zone of hydrothermal alteration (Figure 2) is present in the Malitbog sector which contains montmorillonite and, at higher temperatures, interlayered illite-montmorillonite (140-230°C) and, above 230°C, illite. This mineral assemblages is in equilibrium with present-day geothermal fluids, since their temperature stability ranges are in close agreement with present downhole temperatures. This zone is encountered from -600 m to -1650 m RSL and is superimposed on the propylitic and potassic zones of the previous fossil hydrothermal regime.

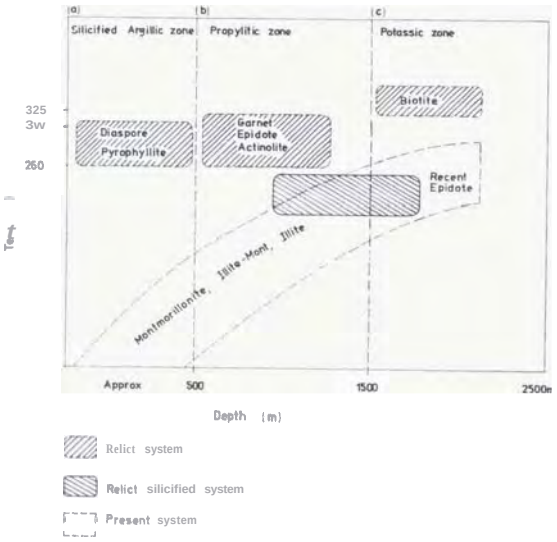

Figure 3: Alteration Zones in the Malitbog Sector.

Petrology of Malitbog Well 506

501, the first deep well in the Malitbog sector, was completed to a depth of 1665 m in March 1978. This well and three further exploration wells, 502, 503 and 504 confirmed further extension of the resource. The next three wells 505–D, 506–D and 507–D were sited to delineate wells to the south and east. Although hot, none sustained discharge. Strong silicificadist and low permeability characterized all three wells and as such suggested limits of the exploitable Malitbog Field, at least to drilled depths.

Borehole Geology (Figure 4)

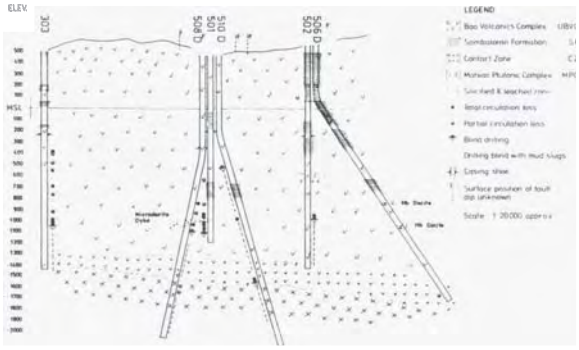

Figure 4: Malitbog Sector Geological Section A–A' (section line shown on Fig 1.)

The well intersected silicified and propylitized tuffs and andesites to –1500 RSL and a contact zone of propylitized quartz andesites and microdiorites from –1500 m RSL to T.D. 2297 m (V.D.).

Alteration Mineralogy (Figure 5)

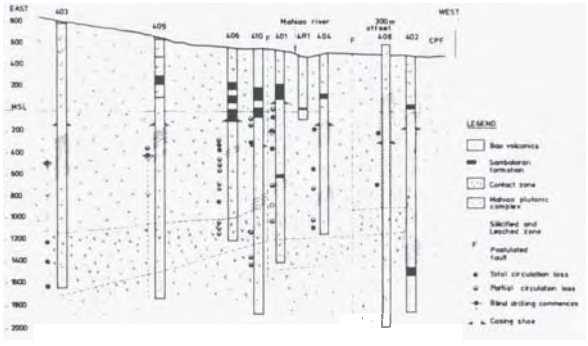

Figure 5: Mahiao Sector Geological Section B-B' (section line shown on Fig. 1)

Petrography of core and cuttings indicated a dominantly relict mineralogy represented by propylitic and potassic zones. The most extensive of these is the propylitic zone with epidote present between –650 m to –1730 RSL (T.D.). Accessory minerals include anhydrite, actinolite, chlorite, pyrite and rare calcite. Relict potassic and propylitic zones are present between –1000 m RSL T.D. A recent hydrothermal zone containing montmorillonite and illite/montmorillonite is in equilibrium with present day downhole temperatures. Clays were identified by XRD techniques using water based oriented samples which were then glycolated and heated to 150°C and 550°C respectively for one hour.

Fluid Inclusions

Fluid inclusions homogenization temperatures between 240–250°C were measured from anhydrite in core at 2297 m (TD). These temperatures are approximately in equilibrium with present measured downhole temperatures at T.D.

Most inclusions present were vapour inclusions which accounts for the few measurements made. Salinities of 4 inclusions were measured on a freezing stage by Evelyn Napoles (see references) who noted inclusions of daughter minerals and recorded very high salinities around 40% NaCl equivalent. These salinities and the presence of daughter inclusions described by Nash (see references). Halite–bearing inclusions are characteristic of porphyry copper deposits.

Petrology of Mahiao Deep Well 410

410 drilled as a production well was completed in April 1981 to a depth of 2360 m. From well testing temperatures of 330°C were recorded near bottom hole. Production zones are present at 1200–1250 m and 2300–2350 m.

Borehole Geology (Figure 6)

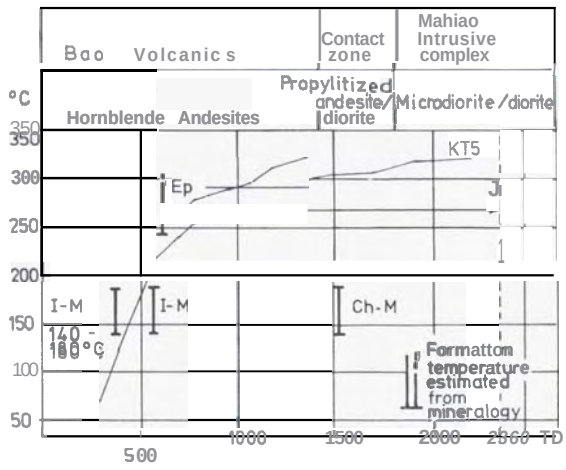

Figure 6: Mahiao 410 Lithology and Alteration Mineralogy

The well intersected some 1500 m of Bao Volcanics with intercalated Sambaloran formation from +200 m to -1000 m RSL. Between -1000 m to -1300 m RSL a contact zone of propylitized andesites and diorites was encountered. From -1300 m to -1900 m RSL diorite was intersected.

Alteration Mineralogy (Figure 7)

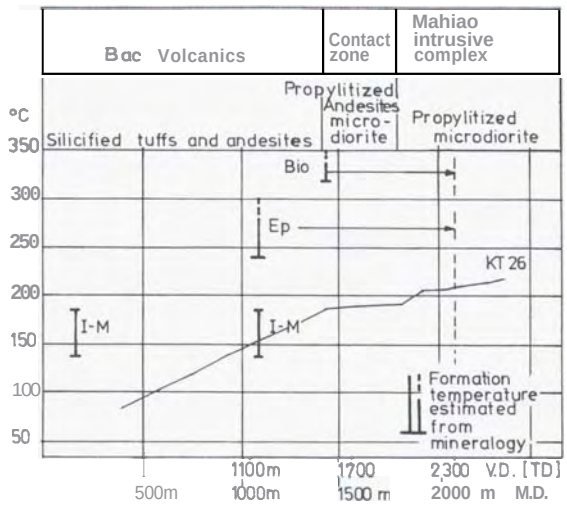

Figure 7: Malitbog 506-D Lithology and Alteration Mineralogy

The mineral assemblage from cores and cuttings in 410 is dominantly propylitic from -100 m RSL to T.D. (2360 m). A potassic zone was not observed from the mineralogy. Calcite which is rare in 506-D is common throughout 410. Illite-montmorillonite and illite-chlorite interlayered clays were observed from x-ray diffraction traces.

CONCLUSIONS

(1) Lithologies of the Mahiao and Malitbog sectors in the Tongonan Field are similar. The thickest sequence encountered (Bao Volcanics) during drilling comprises fresh to propylitized andesites. This lithology is intersected from surface to approximately -1500 m RSL.

(2) Four phases of hydrothermal atleration have been observed in the Malitbog Field:-

(a) potassic
(b) propylitic
(c) advanced argillic
(d) low grade hydrothermal alteration

The most extensive zone observed is the propylitic (epidote) zone is thought to be relict at shallow depths -200 m to -600 m RSL. Below this epidote appears to be in equilibrium with present downhole conditions. The potassic zone is characterized by biotite and is dominantly relict. The advanced argillic zone is characterized by the presence of diaspore and pyrophyllite and is intermittently present in Malitbog wells. It is considered relict because acidic fluids are not currently observed in this sector. Low temperature hydrothermal alteration minerals comprise montmorillonite, illite and inter-layered clays which are in equilibrium with present downhole temperatures.

(3) Mineralogy in drillholes 506-D and 410 vary considerably. 506-D has a zone of relict propylitic (epidote) and potassic (biotite) assemblages. 410 has a dominantly recent propylitic (epidote) assemblage. Calcite, which is rare in 506-D is common in 410.

(4) 410 is a high temperature relatively permeable well with bottom hole temperatures of 330°C. 506-D has maximum bottomhole temperatures of 250°C and could not sustain a discharge.

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REFERENCES

Browne, P. R. L. 1978 Hydrothermal alteration in active geothermal fields. Ann. Rev. Earth Planet Sci. 6:229-50

Ellis, A.J., Mahon, W.A.J. 1977. Chemistry in Geothermal Systems. New York: Academic

Heinrich, E.Wm. 1965. Microscopic Identification of Minerals. New York: McGraw-Hill

Leach, T.M. and I. Bogie. Overprinting of hydro-thermal regimes in the Okoy geothermal field, Southern Negros, Philippines. Proceedings Pacific Geothermal Conference, 1982

Napoles, E.M. Fluid inclusion study of core samples from the Malitbog thermal and Tongonan geothermal field, Philippines. Auckland University Geothermal Institute, 1981

Nash, J. Thomas, 1976. Fluid-Inclusions Petro-logy-Data from Porphyry Copper Deposits and Applications to Exploration. (U.S.) Geological Survey Professional Paper 907-D. Washington: U.S. Government Printing Office

Reyes, Agnes G, 1979. The borehole geology and alteration mineralogy of Malitbog-1, Tongonan, Leyte, Philippines. UNU Geothermal Training Programme Report 1979-1

Robson, R.N., 1979: Geology of a mineralised porphyry system: Whangapoua, Coromandel

Pennisula. Unpubl. MsC Thesis, University of Auckland

Steiner, A. 1976. Clay minerals in hydrothermally altered rocks at Wairakei, New Zealand Clays and Clay Minerals 16: 193–213

Sudo, T. and Shimoda, S. 1977. Interstratified Clay minerals - mode of occurrence and origin. Minerals Science and Engineering 9:No. 1 : 3–24.

Williams, H., Turner, F.J., Gilbert, C.M. 1955. Petrography: an introduction to the study of rocks in thin section. San Francisco, W.H. Freeman and Co.