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History of geothermal exploration in Indonesia from 1970 to 2000

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Abstract

Reconnaissance surveys undertaken since the 1960s show that more than 200 geothermal prospects with significant active surface manifestations occur throughout Indonesia. Some 70 of these were identified by the mid-1980s as potential high-temperature systems using geochemical criteria of discharged thermal fluids. Between 1970 and 1995, about 40 of these were explored using geological mapping, geochemical and detailed geophysical surveys. Almost half of the surveyed prospects were tested by deep (0.5–3 km) exploratory drilling, which led to the discovery of 15 productive high-temperature reservoirs. Several types of reservoirs were encountered: liquid-dominated, vapour-dominated, and a vapour layer/liquid-saturated substratum type. All three may be modified by upflows (plumes) containing magmatic fluid components (volcanic geothermal systems). Large, concealed outflows are a common feature of liquid-dominated systems in mountainous terrain. All explored prospects are hosted by Quaternary volcanic rocks, associated with arc volcanism, and half occur beneath the slopes of active or dormant stratovolcanoes. By 1995, five fields had been developed by drilling of production wells; three of them supplied steam to plants with a total installed capacity of 305 MW_e. By 2000, with input from foreign investors, the installed capacity had reached 800 MWe in six fields, but geothermal developments had stalled because of the 1997–1998 financial crisis.

Keywords: Geothermal exploration; High-temperature prospects; Selection criteria; Exploration surveys; Exploratory drilling; Java; Sumatra; Sulawesi; Bali; Flores; Indonesia

1. Introduction

Geothermal exploration in Indonesia began in 1970 with the aim of finding and developing high-temperature geothermal systems. The developments between 1970 and 1990 (in many cases

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until 1995) are not well documented. An attempt is made here to summarize the early surveys, referring to information in publications and reports written in English, mainly by Indonesian scientists and engineers, which are accessible in the public domain. Thus, the exploration of prospects is discussed where detailed geological, geochemical, and geophysical methods were combined to assess field characteristics of importance when siting exploration wells over inferred high-temperature reservoirs. Results of early geophysical surveys are discussed in more detail where they led to proper estimates of reservoir areas and, combined with important geochemical and geological findings, allowed a prediction of reservoir characteristics. Since most of the earlier exploration efforts are not listed in the scientific literature, theses and diploma reports of Indonesian geothermal graduate students attending the University of Auckland between 1979 and 2003 became an important source of information and were used for this paper. The geothermal terminology employed here is that adopted in Hochstein and Browne (2000). The description of a few prospects not covered by published work is based on observations and field notes collected by the authors.

Descriptions of Indonesian geothermal resources probably started with the reconnaissance surveys described by Junghuhn over 150 years ago (Junghuhn, 1854), whose studies covered mainly active volcanoes and large thermal areas on Java. From around 1900 until the beginning of World War II, most of the Indonesian Quaternary volcanoes and their fumarole and solfatara fields were mapped by the Dutch colonial Geological Survey; the results were later published in the first volume of the Catalogue of the Active Volcanoes of the World (Neumann van Padang, 1951). A summary of documented thermal springs on Java, the Molucca Islands, and Sumatra can be found in the lists of global thermal springs by Waring (1965). After Indonesia gained independence, the Volcanological Survey of Indonesia (VSI) started work in the 1960s with reconnaissance-type surveys that led to the compilation of an inventory of sites with thermal manifestations. A map showing the location of these sites on Java and Bali was compiled by VSI in 1968 (Purbo-Hadiwidjojo, 1970). The studies were supported by the State Electricity Company (PLN) and the Bandung Institute of Technology (ITB). International and foreign missions (UNESCO, EURAFREP) visited several geothermal prospects at that time and, with reference to the size and type of manifestations, drew attention to prospects associated with hot spring discharges. A revised catalogue of volcanoes and fumarole fields in Indonesia published by VSI (Kusamadinata, 1979) provided important information now incorporated in a world-wide catalogue of volcanoes that can be accessed through the Smithsonian volcano website (see bottom of Table 1).

All Indonesian geothermal systems associated with surface manifestations discharging fluids at boiling temperature occur in areas with Quaternary volcanism and active volcanoes along well-defined volcanic arcs. There are five active arc segments in Indonesia that define regions of interest for geothermal exploration (Fig. 1). Using plate tectonic concepts, all active Indonesian arcs can be interpreted as the result of sub-crustal melting induced by subducted lithosphere plates (Katili, 1975). The major plate tectonic structures shown in Fig. 1 had already been recognised during the 1970s (Hamilton, 1979). All young Quaternary volcanoes can be associated with cooling magma and igneous intrusions, which, in turn, are heat sources for active arc-type geothermal systems.

The first inventory (in English) of Indonesian thermal areas and prospects, compiled by VSI as part of a New Zealand (NZ) Aid project in 1987 (NZMFA, 1987; Mahon, 1987), listed 215 sites. The inventory has been upgraded and about 245 thermal prospects are listed in its 1998 version, which is accessible through a VSI website (see bottom of Table 1). We have used the same names, numbering system, and coordinates of the geothermal sites shown in the 1998 VSI catalogue (with the exception of a few not yet given there). A list of 87 Indonesian geothermal