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GEOTHERMAL DEVELOPMENT IN INDONESIA: AN OVERVIEW OF INDUSTRY STATUS AND FUTURE GROWTH

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ABSTRACT

Indonesia may have the highest geothermal power potential of any nation, with a geothermal resource base of nearly 20,000 MW, as estimated by Pertamina. From 1973 to 1998, 17 geothermal areas were drilled to explore, confirm, and develop geothermal resources in Java, Sumatra, Bali, Flores, and Sulawesi. As of July 1999, five geothermal fields are operating in Indonesia with a combined installed capacity of 527 MW.

Since 1982, geothermal development in Indonesia has been expedited by government regulations that allow the participation of the private sector, both local and international, in partnership with Pertamina. By 1994, Pertamina and two private developers, together with the government utility PLN, completed geothermal projects at Kamojang (140 MW), Salak (110 MW), and Darajat (55 MW). Seven private geothermal companies signed contracts of joint operation with Pertamina for 10 contract areas between 1994 and 1997. As a result of these contracts, an additional 220 MW started commercial operations at Salak in 1997, and three additional power projects comprising 240 MW were constructed at Wayang Windu (110 MW), Darajat (70 MW), and Dieng (60 MW) in Java. Pertamina has been independently developing smaller pilot projects in Sumatra and Sulawesi. The severe economic crisis that started in late 1997 has adversely affected power sector demand and growth in Indonesia. This has resulted in significant delays to several geothermal projects in the advanced exploration and development stages. Changes in the regulatory environment for the geothermal industry and the resolution of the economic crisis are the major issues affecting the future growth of the Indonesian geothermal industry.

1. INTRODUCTION

The Indonesia archipelago has numerous active volcanoes associated with a 7000 km-long plate boundary (*Figure 1*) along which there is both convergent and strike-slip movement. This has given rise to a large concentration of high-temperature geothermal systems on or close to the plate margins in Sumatra, Java, Nusa Tenggara, Sulawesi and Halmahera (*Figure 2*).

Geothermal energy exploration started in Indonesia in the early 1900's. The Dutch drilled successful shallow test wells at Kamojang, West Java, in the 1920's, and started a country-wide inventory of thermal features. The Indonesian government conducted a more complete inventory in 1972 with technical assistance from Italy, Japan, New Zealand, and USA. The results of these studies were used as a basis to issue new policies to accelerate geothermal development and encourage energy diversity in the country. To implement the new policies, the government issued a decree in 1974 appointing the state-owned oil company Pertamina to explore and develop geothermal energy in conjunction with domestic and international partners.

At least 70 high enthalpy geothermal fields and prospects have been identified in Indonesia (Figure 2). Pertamina has estimated that the combined potential of these resources represents about 20,000 MW (Fauzi, 1998; Pertamina, 1994). Indonesia may have the highest geothermal potential in the world.

2. GOVERNMENT POLICIES

In 1974, through Presidential Decree No. 16/1974, the Indonesian government appointed Pertamina to conduct exploration and operation of the geothermal fields. This decree allowed Pertamina to operate the Kamojang field and to explore other geothermal resources in Indonesia.

The Government of Indonesia issued Presidential Decree No. 20/1981 allowing Pertamina to enter joint ventures with local and international partners. The presidential decree led to endorsement of a Joint Operations Contract (JOC) between Pertamina with Unocal Geothermal of Indonesia Ltd., and an Energy Sales Contract (ESC) with the State Electric Company (PLN) for the Gunung Salak contract area, West Java, in 1982. Amoseas Indonesia signed a JOC with Pertamina and an ESC with PLN for the Darajat contract area in 1984.

Presidential Decree No. 45/1991 allowed the Pertamina partnerships to build and operate geothermal power plants. Another presidential decree, No. 49/1991 was promulgated to provide economic incentives to support implementation of the preceding decree, No. 45/1991. Both regulations sought to accelerate development of geothermal projects under Pertamina management. Tables 1 and

2 summarize the status of the geothermal projects instituted under these decrees.

Because of the economic crisis that began in late 1997, the government of Indonesia issued Presidential Decree No. 5/1998. This decree has resulted in significant delays to geothermal projects in the advanced exploration and development stages at Sarulla, Darajat, Kamojang, Dieng, Patuha, Karaha, and Sibayak (Table 2).

3. SUMMARY OF GEOTHERMAL DEVELOPMENT

Large scale geothermal development first started at Kamojang, West Java, in 1983 (Radja, 1995). Pertamina and PLN, the State Electric Company, installed 140 MW of steam gathering facilities and power plants, respectively, and the power was sold through the Java-Bali grid. Subsequent projects were developed by private foreign companies in partnership with Pertamina. The first private development contracts were signed in 1982-84, but initial development was slow, with power generation commencing at Gunung Salak (110 MW) and Darajat (55 MW), West Java, in 1994 and 1995, respectively (Sussman et al., 1997). Seven private geothermal companies signed contracts of joint operation with Pertamina for 10 contract areas between 1994 and 1997. As a result of these contracts, an additional 220 MW started commercial operations at Salak in 1997, and three additional power projects comprising 240 MW were constructed at Wayang Windu (110 MW), Darajat (70 MW), and Dieng (60 MW) in Java. Pertamina independently developed smaller pilot projects in Sumatra and Sulawesi. Currently there are five geothermal operating power projects comprising 527 MW, and another 240 MW have been built but are not yet operating.

3.1. Operating/Developed Fields

Seven geothermal fields are in various stages of operation and development, including Kamojang, Salak, Darajat, Wayang Windu, and Dieng, which are all on Java, Sibayak on Sumatra, and Lahendong on Sulawesi.

Kamojang

Kamojang is located in West Java, 40 km southeast of Bandung city. Pertamina operates the steam field and supplies steam to three PLN power plants comprising 140 MW. Kamojang is a vapor-dominated system with an average reservoir temperature and pressure of about 245^{o}C and 35 bars, respectively. Thirty-one wells drilled in an area of 14 km^2 supply 1050 tons/h of steam to the plants, which were installed in 1983-1988. Twenty-nine wells capable of supplying an additional 60 MW of steam were drilled in 1996-97, however a planned 60 MW plant has been postponed due to Presidential Decree 5/1998.

Salak

Gunung Salak field is located 70 km south of Jakarta in West Java. Unocal Geothermal of Indonesia operates the steam field, which supplies six 55 MW power plants. Units 1 and 2 were built by PLN and came on-line in March 1994. Units 3-6 started commercial operations in 1997. Unit 3 was constructed by PLN, and Units 4-6 were built by Unocal. PLN operates Units 1-3 and Unocal operates Unit 4-6. With 32 production and 19 injection wells, the power plants are capable of generating at least 345 MW. The six units have maintained an 80% capacity factor or higher since start up. The Salak field hosts a neutral-Cl liquid-dominated reservoir with temperatures ranging from 240^{o}C to 310^{o}C (Soeparjadi et al., 1998, and Slamat, 2000, this volume).

Darajat

Darajat is located 60 km southeast of Bandung, West Java. The steam field and the first 55 MW power plant are operated by Amoseas of Indonesia Inc. and PLN, respectively. The Darajat reservoir is vapor-dominated with a temperature of about 245^{o} C. Eight wells produce sufficient steam to operate Unit 1. Amoseas drilled 17 more development wells and constructed a second unit of 70 MW in early 1999. However, due to Presidential Decree 5/98 the project has been postponed, and the plant and resource production facilities were suspended after commercialization testing.

Dieng

Dieng is located 60 km southwest of Semarang, Central Java. Dieng is operated under JOC with Pertamina and ESC with PLN and Himpurna California Energy, Ltd (HCE), which constructed both the steam field and power plant. HCE drilled 25 wells to produce sufficient steam for the 60 MW power plant, which was commissioned in July 1998. The geothermal system is dominated by two-phase conditions with temperatures of 280^{o}C to 330^{o}C. Although this project was not discontinued by PD-5/1998, the power plant is not generating power.

Wayang Windu

The Wayang Windu field is located 40 km south of Bandung in West Java. The reservoir is liquid-dominated, and temperatures range from 250^{0} to 270^{0}C. The resource production facilities and 110 MW power plant were built by Asia Power/Mandala Nusantara under “total project” contracts. The power plant and the steam facilities were completed and tested in July 1999. A total of 18 wells have been completed and are capable of supplying about 185 MW of steam (Wheble, pers. comm., 1999). As of February 2000, the power lines to the plant were not complete.

Sibayak

Sibayak is located within a Quaternary caldera about 50 km southwest of Medan, North Sumatra. Pertamina and PT. Dizamatra are developing the Sibayak geothermal field. Pertamina manages the steam field and plans to supply steam to a future 20 MW private power plant. Through July 1999, 10 wells have been drilled, which have a proven capacity 25 MW. Since 1995, one well has been supplying steam to a 2 MW back-pressure power plant installed and operated by Pertamina to supply the local power grid. The reservoir is liquid-dominated with temperatures from 240^{o} C to 275^{o} C.

Lahendong

Lahendong is located 40 km south of Manado in North Sulawesi and has been under development by Pertamina since 1984. Fifteen exploration and development wells have been drilled with a proven generating capacity of 30 MW. In 1992, a 2.5 MW binary power plant was installed at Lahendong, but the plant has not gone into commercial operation. In May 1999, Pertamina signed a contract with PLN to supply steam to a 20 MW power plant to be constructed by PLN. The plant is expected to be operating commercially by the year 2001. The reservoir is liquid-dominated, with relatively high temperatures ranging from 260^{o} C to 330^{o} C.

3.2. **Confirmed Geothermal Resources**

Geothermal resources have been confirmed through exploration drilling at three contract areas: Sarulla in North Sumatra, and Patuha and Karaha in West Java.

Sarulla

The Sarulla Contract Area is located 300 km south of Medan in North Sumatra. Between 1993 and 1997 Unocal North Sumatra Geothermal Ltd. (UNSG) drilled 13 wells in three different prospects and discovered high temperature geothermal systems in each area. These include Silangkitang, Namora-I-Langit, and Sibualbuali (Gunderson et al., WGC 2000, this volume). Resource feasibility studies have been submitted to Pertamina in support of the first 330 MW development at Silangkitang and Namora-I-Langit. Both projects have been postponed due to PD 5/98.

Patuha

The Patuha field, which is located 50 km south of Bandung, has been explored by Patuha Power Limited (PPL) as a Joint Venture between California Energy Company and a local partner under JOC with Pertamina, and ESC with PLN. PPL drilled 13 conventional exploration wells, 17 slim holes and 6 development wells since 1994. A moderate to high temperature reservoir has been discovered (175^{0}C to 245^{0}C). The development of this field has been postponed by PD 5/1998.

Yala Teknosa has drilled two exploration wells at the Cibuni prospect on the western flank of Gunung Patuha. Pertamina does not administer the contract for Cibuni because it is a small scale geothermal project and falls under different government regulations. The wells have discovered commercial reservoir temperatures, but exploration activities have been suspended.

Karaha

The Karaha field is located 80 km east of Bandung in West Java. Karaha Bodas Co. (KBC), a partnership of Caithness and Florida Power and Light, has explored Karaha under a JOC with Pertamina and ESC with PLN. KBC has drilled nine conventional exploration wells and 19 slim holes, discovering a liquid-dominated resource overlain by a steam cap. Reservoir temperatures range from 230^{o}C to 245^{o}C. Presidential Decree 5/1998 has postponed project development.

3.3. Drilled Fields

Exploration drilling has been conducted at seven geothermal areas in Sumatra, Java, Bali and Flores. Additional exploration drilling is required in order to confirm commercial geothermal resources at these prospects.

Sumatra

The Volcanological Survey of Indonesia (VSI) drilled 2 slim holes in 1981 and one exploration well in 1999 at the Lempur prospect, which is located in Central Sumatra about 250 km south of the city of Padang. The wells discovered a liquid-dominated resource with temperatures from 150^{o}C to 200^{o}C which combined have an estimated capacity of 3.5 MW.

Three exploration slim holes were drilled by Pertamina at the Ulubelu field in South Sumatra. Ulubelu is located 100 km west of Bandar Lampung. The wells encountered a steam cap overlying a liquid-dominated resource with temperatures from 210^{0}C to 230^{0}C.

Java

During the mid-1980's Pertamina drilled one exploration well each at the Banten and Cisolok prospects in West Java. An exploration slim hole was also drilled by Pertamina in 1992 at the Wilis-Ngebel prospect in East Java. None of the three wells discovered a high temperature geothermal resource.

Bali and Flores

The Bedugul field, which is located on Bali about 60 km northwest of Denpasar, has been explored by Bali Energy, a joint venture between a national company and California Energy under a JOC with Pertamina and an ESC with PLN. Three conventional exploration wells and six slim holes have

encountered reservoir temperatures from 245°C to 340°C. Further resource evaluation was postponed because of Presidential Decree 5/1998.

On the Island of Flores, PLN drilled three conventional exploration holes at the Ulumbu prospect. The wells have been completed in a steam cap with a temperature of 230 – 240°C.

3.3. Undrilled Prospects

Surface exploration surveys have been conducted at 34 other prospects in Indonesia. Six of these prospects have been brought to the exploration drilling stage, including Sorik Merapi, Muaralabuh, Lumut Balai, Rajabasa, Tompaso and Kotamobagu. The other 28 prospects are at different stages of exploration.

4. INDONESIA'S GEOTHERMAL FUTURE

The abundance of geothermal energy in Indonesia makes it an important natural resource for future energy development. Until the 1997 economic crisis, the regulations enacted by the Government of Indonesia successfully promoted the rapid exploration and development of these resources for electrical power, meeting Indonesia's desire for better energy diversity. As a result of government promotion, 12 geothermal contracts have been signed with total contract commitment of about 3417 MW (Fauzi, 1998). When Indonesia recovers from the economic downturn, geothermal power can once again represent an important energy source to meet the expected growing demand for electricity.

Future geothermal energy development will be dependent on constructive actions that both the developers and the government can undertake together. Geothermal developers must recognize that geothermal energy needs to be competitive with the prices of other fuel sources for electrical generation. The Indonesian government can assist the industry by recognizing and rewarding some of the intangible benefits of geothermal power, such as its indigenous nature and well-recognized environmental benefits.

More importantly, if the government wishes continued participation by the private sector, the government must demonstrate that it can and will meet its future contractual obligations. With a strong commitment by both the private sector and the Indonesian government, the tremendous geothermal potential in Indonesia can be unlocked to provide electricity for future generations.

5. CONCLUSIONS

The Indonesian geothermal industry has made impressive strides under the Indonesian government's energy policies and Pertamina's contract administration to develop the geothermal potential of Indonesia. The signing of twelve contracts has led to commitments for the development of 3475 MW capacity, including 527 MW now on-line with another 240 MW available for generation. In addition, more than 30 prospects are in various stages of exploration. The aggressive push towards geothermal development over the past decade sets the stage for a robust geothermal industry once the economic crisis subsides and the demand for electricity resumes growing.

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Table 1. Installed geothermal power plants in Indonesia.

Area	Capacity In Operation (MW)	Capacity Installed But Not Operating	Operator/ Contractor
Kamojang	140		Pertamina
Sibayak	2		Pertamina
Lahendong		2.5	Pertamina
G. Salak	330		Unocal
Darajat	55	70	Amoseas
Dieng		60	Cal Energy
W. Windu		110	Asia Power / Mandala
Total	527	242.5	

Table 3. Geothermal wells drilled by Pertamina, PLN, and VSI.

Prospect	Well			Total	Remarks
	Expl	Slim	Dev.		
Kamojang	5	-	62	67	Prod.
Lahendong	10	-	9	19	
Banten	1	-	-	1	Aband.
Cisolok	1	-	-	1	Aband.
Sibayak	3	-	7	10	
Lempur	2	1	-	3	
Ulubelu	-	3	-	3	
Ulumbu	3	-	-	3	
Cibuni	2	-	-	2	Aband.
Wilis	-	1	-	1	Aband.
Total	28	4	78	110	

Table 4. Geothermal wells drilled under JOC.

Area	Well			Total	Remarks
	Expl	Slim	Dev.		
Darajat	3	6	21	30	Prod.
Salak	6	-	51	57	Prod.
Sarulla	4	9	-	13	
Dieng	1	5	19	25	Prod.
Patuha	13	17	6	36	
Karaha	9	19	-	28	
W.Windu	8	4	15	27	Exploit.
Bedugul	3	6	-	9	
Total	43	66	112	261	

Table 2. Indonesian Geothermal Power Plant contracts

#	Project / Year contract signed	Contract Capacity (MW)	Contractor	Status on PD5/1998
1.	Kamojang Units1,2,3 1984	140	Pertamina	On-line
2.	Salak 1982 amended 1994	495	Unocal	On-line
3.	Darajat 1984; 1996	330	Amoseas	55MW on-line; 70MW postponed
4.	Sarulla 1993	330	Unocal	Postponed
5.	Dieng Unit 1-4 1994	400	CalEnergy	Units 1-3 continued; Unit 4 postponed
6	Kamojang U 4,5,6 1994	60	Latoka	Reviewed
7	Karaha 1994	400	Caithness	Postponed
8	Patuha 1994	400	CalEnergy	Unit 1 reviewed; Units 2-4 postponed
9	Wayang Windu 1994	400	Asia Power/ Mandala	Continued
10	Bedugul 1995	400	CalEnergy	Unit 1,2 reviewed; Unit 3,4 postponed
11	Cibuni 1995	10	Yala Teknosa	Postponed
12	Sibayak 1996	120	Pertamina/ Dizamatra	Postponed
13	Lahendong 1999	20	Pertamina	Continued
Total:		**3475**		

Notes:
Continued: Allowed to proceed with development
Postponed: Development delayed until PD5 revoked
Reviewed: Under consideration to be continued or cancelled

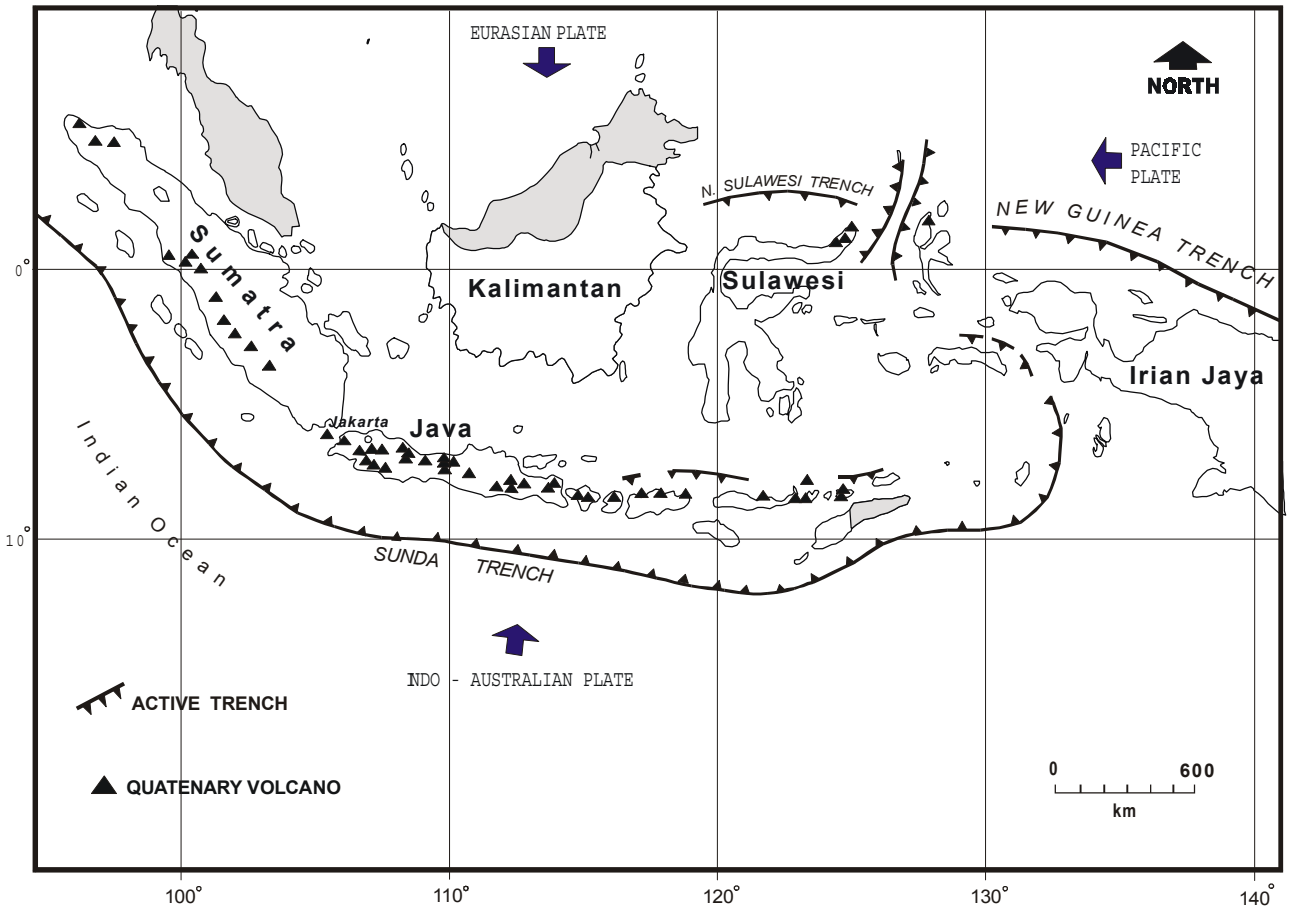
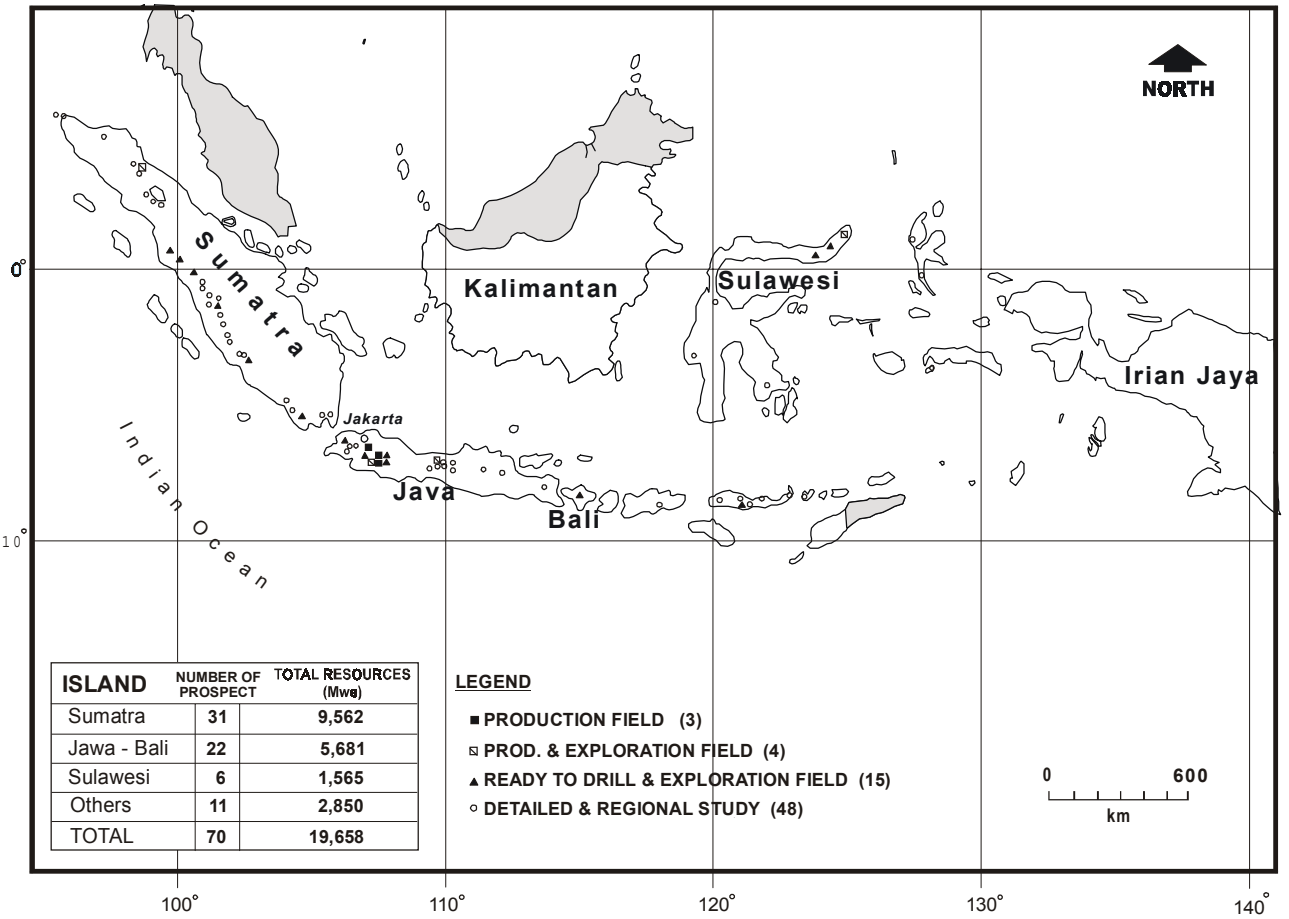


Figure 1. Active volcanic belts in Indonesia



ISLAND	NUMBER OF PROSPECT	TOTAL RESOURCES (Mwe)
Sumatra	31	9,562
Jawa - Bali	22	5,681
Sulawesi	6	1,565
Others	11	2,850
TOTAL	70	19,658

Figure 2. Geothermal resources in Indonesia