PRESENT STATUS AND TASKS OF THE OGACHI HDR PROJECT

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ABSTRACT

The CRIEPI's Ogachi HDR Project has begun in 1989 with the objective of developing elemental technologies to make economically available geothermal energy. Two reservoirs, the upper and the lower, were created by drilling of a 1,000m well (the injection well) and by hydraulic fracturing in the basement rock of granodiorite at Ogachi, in Akita Prefecture, Japan. In 1993, another well (the production well) with a 1,100m depth was drilled intersecting both of these reservoirs. After two circulation tests and some reservoir stimulations using these two wells from 1993 to 1995, a one month circulation test was conducted in 1995 and hot water and vapor of 165 ℃ were produced at a rate of 7.5m^3/hour from the production well when water of 20 ℃ was injected at a rate of 30m^3/hour from the injection well.

These accomplishments have been supported and paralleled by developments in various technologies such as the microseismic fracture mapping technique, the multiple-reservoir creation technique, the geology and geochemistry studies, and many instruments to obtain hydraulic and thermal data etc.

The most important task for the next step at Ogachi is the evaluation of the reservoir by some data analyses and a 3D-simulation method.

INTRODUCTION

Advancements in geothermal energy are giving new dimensions to the development of clean natural energy resources. CRIEPI(Central Research Institute of Electric Power Industry) has been applying its research expertise to the development of Japan's abundant geothermal resources as part of a grand strategy for the diversification of energy sources designed to reduce both dependency on petroleum and environmental pollution.

CRIEPI has been conducting Hot Dry Rock Geothermal Energy Development(HDR) experiments at Ogachi in Akita Prefecture, northeast Japan (See Fig.-1,2)since the beginning in 1989, after the Akinomiya Project (phase- I ,1986-1988) as a preparation stage for the Ogachi

Project.

This paper outlines the present status of the Ogachi Project reaching through our experiments since 1989 and the tasks to solve for making an advance in future.

1. RESULTS OF EXPERIMENTS FROM 1990 TO 1994

The Ogachi site is situated in the mountainous region of the elevation of about 600m. The geology of the Ogachi site consists of Cretaceous granodiorite covered with Tertiary lappily tuff to a depth of 300m from the ground surface(Fig.-3). A number of pre-existing or natural joints are developed in the granodiorite, the mother rock of hydraulic fracturing, with an average spacing of about 8 cm observed from the geological investigation but with a comparably low natural permeability obtained from the result of an initial flow test.

In 1990, second year of the phase-II(1989-1992), an injection well was drilled to a depth of 1,000m where the rock temperature was measured at 228 ℃, and a casing pipe was set in the well except a 10m section at the bottom. In 1991, over 10,000 m^3 of water was injected from the open-hole section at the bottom of the well,creating a fractured area with 200m thick and 500m wide that estimated to stretch 1,000m in the direction of 20 degrees NNE from AE hypocenters distribution.

After the lower fracture completed, the well's casing pipe were milled from 711m to 719 m to produce an open hole section called a window, then the open-hole section at the bottom was filled with sand. In 1992, an upper fracture was created at the window depth by injecting nearly 5,500 m^3 of water. The upper fracture, also 200m thick, was estimated to extend over a 400 X 800m area in 110 degree ESE direction from AE hypocenters distribution (Fig.-4).

In January,1993, a production well was drilled directionally to a depth of 1,100m to intersect both the lower and upper fractures. The distance between both wells was about 80m at the level of 1,000m depth. After confirming the hydraulic communication by a flow test, a 22 days circulation test was conducted in the phase-III(1993-1995).

In 1994, a 5 months circulation test between the two wells accomplished. The results of the test showed that the recovery rate was about 10% and the injection pressure was 13 MPa at a flow rate of 30 m^3/hour as shown in Fig.-5 . Unless obtaining hot water and vapor of the temperature of 160 ℃, the recovery rate was comparably low and the injection pressure was comparably high to our targets of the test.

2. RESULTS OF EXPERIMENTS SINCE 1995

The principal objectives of the 1995 Ogachi project were to reduce the water injection pressure and to improve the water recovery during water circulation tests. At first we redrilled down the bottom of the injection well from 1,000m to 1,027m to extend the water injection (open-hole) region. After the redrilling, the water injection well was stimulated by injecting water with total volume of 3,400 m^3 at a flow rate of 105 m^3/hour and at a wellhead pressure of 18 MPa. The production well was also stimulated by injecting water with total volume of 4,300 m^3 at a flow rate of 135 m^3/hour and a wellhead pressure of 18 MPa. AE hypocenter location distribution during these stimulations showed that the area around these wells were well fractured.

We conducted a one-month circulation test between these wells to confirm the above mentioned redrilling and stimulation effects. During the circulation test, the water injecting pressure decreased to 7 MPa, about a half of that in 1994, and the injected water recovery from the production well increased to about 25%, about twice as much as that in 1994 (See Fig.-5). In the Fig.-5 , the recovery rate for the last three days in the test term suddenly goes up to 32%, unless no change of the injection rate. What does it mean ? It means a result of the change from 0.8 MPa to 0.6 MPa of the wellhead pressure of the production well by the valve operating.

The produced water temperature of 160 to 165℃ (a maximum of 169℃) was measured.

A tracer test was conducted during this circulation test and the modal volume, a characteristic nature of void volume of major fractures and joints, was 135 m^3 which was about 100 m^3 smaller than that of the tracer tests in 1994 . The resulting in smaller modal volumes was thought to mean the tendency for the water to sweep through new and old fractures of larger aperture around these wells created by these stimulations .

Therefore, we concluded that the extension of the water injection area and the stimulation to these wells were more effective to reduce the water injection pressure and to improve the water recovery.

Through the experiments at the Ogachi site until 1995 , we have a lot of experience and many techniques for HDR development . The table-1 shows some techniques and methods that we have developed or are developing. For example, multiple stage fracturing method, geothermal resource exploration technique using CSAMT, AE observation method for measurement of underground reservoir,etc.

In spite of these many important techniques, new problems or tasks over our prospect, like as the different direction between two reservoirs and the low recovery rate, were produced. So, in 1996, we looked at our previous plan of the Ogachi experiment and presented a new plan of it as shown next two chapters.

3. PRESENT STATUS AND TASKS OF OGACHI PROJECT

In general, it has been said that the technical issues or tasks faced in HDR were as follows:

(1) Well must be drilled to depths where temperature range 200 to 400 ℃, suitable for electric generation.

(2) Such temperature are found at depth of 2 to 5 km where have large in-situ earth stresses. One must then fracture the rock with such temperature and stress, and open the fractures so that the permeability remains high and flow resistance is low.

(3) Large area of hot rock must be adequately bathed to result in high heat production. Since all water must be provided extraneously, losses to the country rock surrounding the fractured reservoir must not be excessive.

(4) The technology development must assure that potentially damaging earthquakes will not caused by downhole accumulation of this water.

(5) One must also avoid potential geochemical problems, such as scaling of surface equipment with precipitated products of rock dissolution and corrosion of surface.

Otherwise, a concept of HDR system has been presented by CRIEPI, which has a power of 240MW using average temperature of 300 ℃ from a hot dry rock and whose well system consists of 5 injection wells and 11 production wells with each depth of 4,000m.

In this chapter, taking account of both the general issues and the conditions involved in our concept, I would like to describe the present status and tasks of the Ogachi Project from two points, the reservoir creation and the recovery products.

(1) Reservoir Creation :

Each reservoir created at Ogachi has an enough size for the heat extraction from the hot mother rock. On the other hand, for an efficient heat extraction from the broad area of ranging from 2 to 4(or 5) km in depth, it needs to create multiple reservoirs having an adequate interval each other. Ogachi's two reservoirs were successfully created at depths of about 700 m and about 1,000 m in the injection well by the method called "Casing Reamer and Sand-plug Method".

(2) Recovery Products :

The temperature of the products recovered from the production well was 165 ℃ and this showed a sufficient value for heat to be obtained. Because the temperature of products at the bottom of the well was over about 230 ℃ (See Fig.-6), nearly equal to the primary rock temperature at the depth. And the deference of the products temperature between at the bottom and the wellhead means no more than an influence of cooling during its rising in the well with a small diameter of about 10cm.

The higher the recovery rate is , the more efficient it is for the HDR power generation. And it has been said that the recovery rate needs to hold at more than 80 % for the following two reasons mainly. One is for an economical operation of the HDR and another is for minimizing the influence of the dispersion of injected water on the circumstance surrounding the reservoirs.

Both at Fenton Hill and Soultz the recovery rate were obtained over 80 %, but at Ogachi only about 25 %. The Fig.-7 shows an image of the Ogachi reservoir structure in 1995. In this picture, the two reservoirs are more simplified for easy understanding, though these have more complicated shapes and different direction each other as before mentioned. And each numeral shows the allotted volume rate per the total volume of the injected water. Certainly, these values are estimated, but have some indirect evidences. Now, if a volume of 100% of water was injected into the injection well, then about 80% of it should flow into the lower reservoir and the remained 20% into the upper . And a total about 25% of it should be recovered from the production well, the 3% should be from the upper reservoir and the 22% from the lower.

There are two problems here. One is how to make the different rate each other even and another is how to evaluate the low recovery rate or the reason why about 75% of total volume of the injected water could not return. The research into the both problems is going on now, as the important our tasks to solve for advance to the next step. Considering of the reason of the latter, it is possible to say that the mother rock, the granodiorite, has a comparably high permeability or has such faults or long open-cracks as a large passage of water flow toward outside the reservoirs. The initial rock permeability measured by the flow tests in the wells at Ogachi has a value of 10^{-6} to 10^{-7} cm/sec, and it's not so high compared with that of other sites. And a possibility of the existence of such faults or open-cracks in contact with the reservoirs cannot completely be denied . Anyway, we are on the way to solve these problems and have not had certain answers yet.

On the other hand, the low recovery rate is also resulting from only one production well, but in our conception mentioned above, four production wells are provided to arrange surrounding one injection well. So it also involved one of the next tasks to solve how much the recovery rate increase to be accompanied by adding of the production well around the injection well.

4. NEXT PLAN OF THE OGACHI PROJECT

We are thinking about the next plan of the Ogachi project as follows:

(1).There are three large tasks to solve.

The first one is the development of an effective reservoir evaluation method, especially how to estimate the situations, the directions and the flowrates of main passages of the injected water in the invisible deep underground.

The second is the development of an evaluation method of the cooling rate of the hot dry rock or the reservoir and the change of reservoir character during long term water circulation in addition to an environmental evaluation.

The third is how to draw an effective prospect for approaching to the realization of a HDR power plant.

(2). For the purpose of the development of the reservoir evaluation method, we are presenting next plan with tow phases, the phase-IV and V, at Ogachi.

In the phase-IV starting from the fiscal year of 1996, the developments of an evaluation method to estimate main fractures or cracks controlling water flow in the reservoir and of a 3D-simulation program to evaluate water flow in the reservoir are involved, accompanied by making of a simulation model accounting for main cracks. And, after getting the hydraulic parameters of each reservoir from the flow test of each reservoir in 1997, a new production well will be drilled at the distance of a few hundred meters away from the injection well, for the purpose of confirming the effective utility of these methods.

Furthermore, in the phase-V, a long-term circulation test among one injection well and two production wells will be conducted for evaluation of the cooling rate of the reservoirs and for the confirming the availability of these evaluation methods mentioned above from the correspondence with the results of the test and its prior estimations by these methods.

These plans are shown in the Fig.-8.

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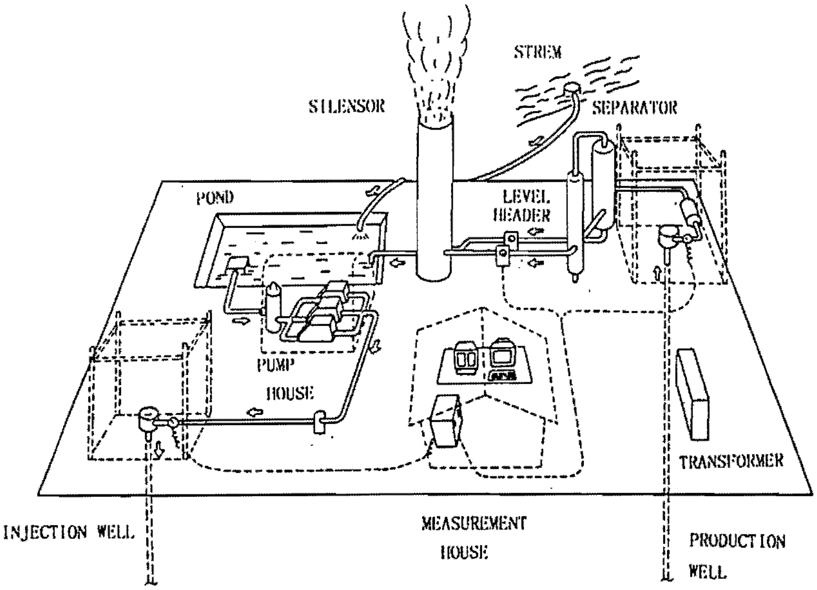

Fig-3. SKETCH OF OGACHI EXPERIMENT SITE

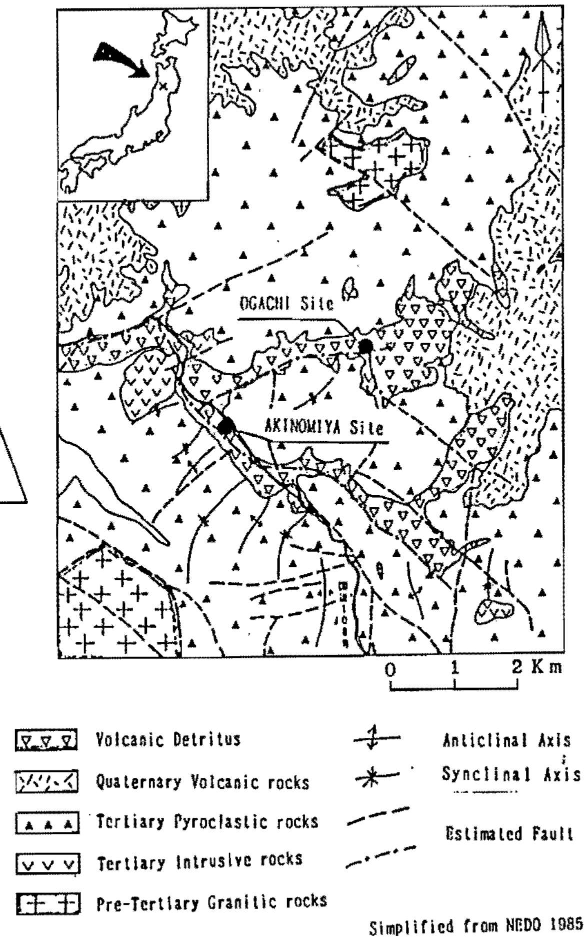

Fig-1. GEOLOGY AROUND OGACHI SITE

Table-1. MAIN HDR TECHNOLOGIES OF CRIEPI

1, HDR Heat Source Prospecting Method
- (1) CSAMT method [until 1-2km depth]
  - (Cotrol sourced audio-frequency magnet tellulic)
- (2) TDEM method [more than 5km depth]
  - (Time domain electro-magnetic)

2, Multiple Fracturing Method
- (1) CRSP fracturing method
  - (Casing reamer·sand plug)

3, Fracture Evaluation Method
- (1) AE method (accourstic emission)
- (2) Mise-a-la-masse method
- (3) Geochemical method
  - (Chemical analysis of fluid, Traser analysis)
- (4) High temperature borehole scanner method
- (5) Continuous temperature measurement method*
  - (Temperature measurement at every depth and in one month by fiber)

4, Reservoir Evaluation Method
- (1) Crack structure elaluation method*
- (2) HDR reservoir simulation method*

5, Inproving HDR Reservoir Method
- Reduction of injection pressure
- Inproving of recovery rate

*; on going

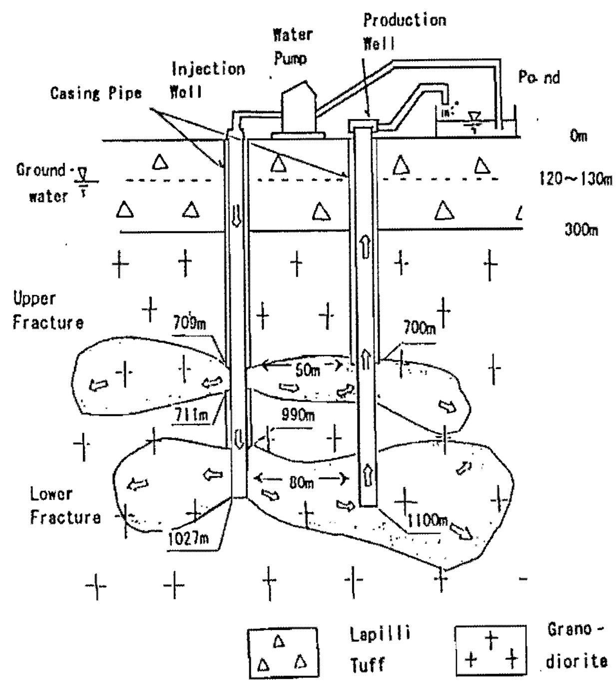

FIG-2. GENERAL PROFILE OF OGACHI SITE

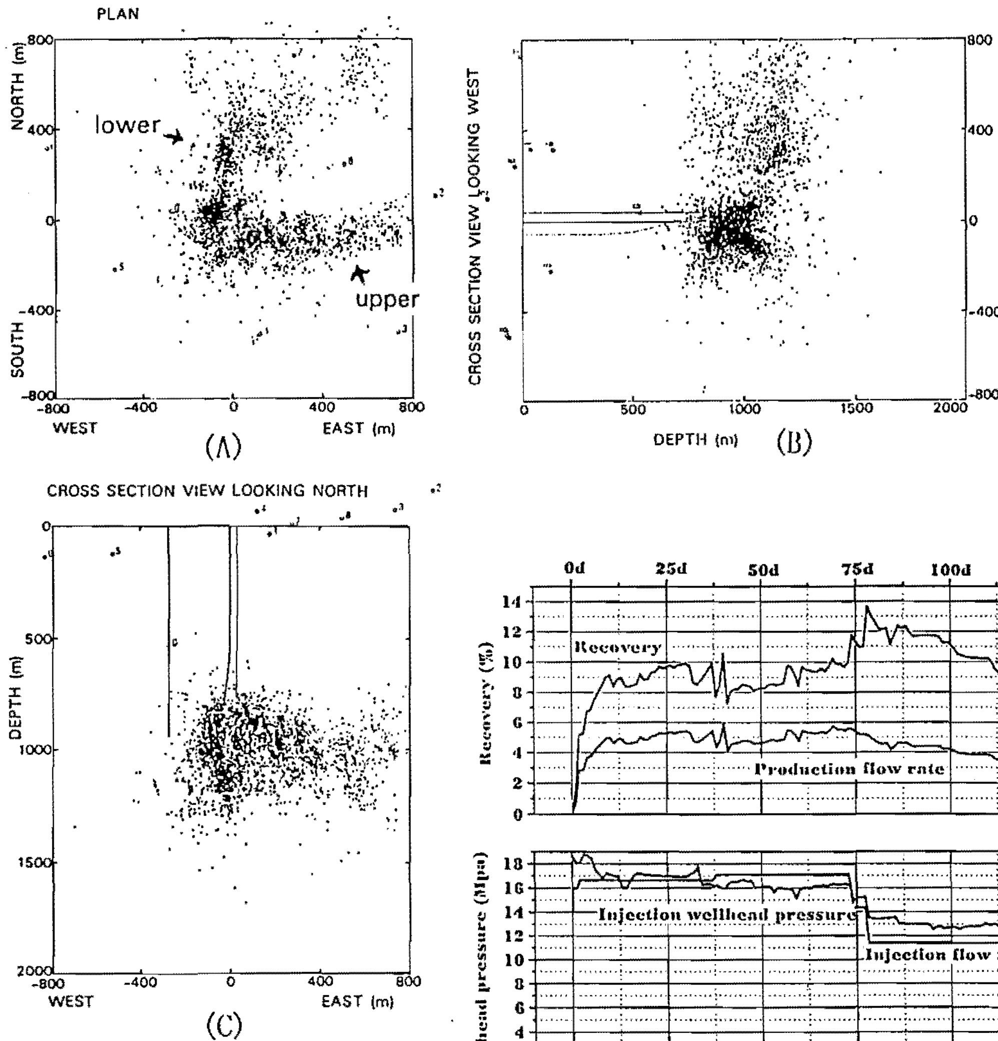

Fig.-4. AE HYPOCENTER DISTRIBUTION

(A) shows the plane view,
(B) shows the N-S cross section view looking West
(C) shows the E-W cross section view looking North.
Circles with number are observation stasions.
Upper shows the upper fracture
Lower shows the lower fracture.

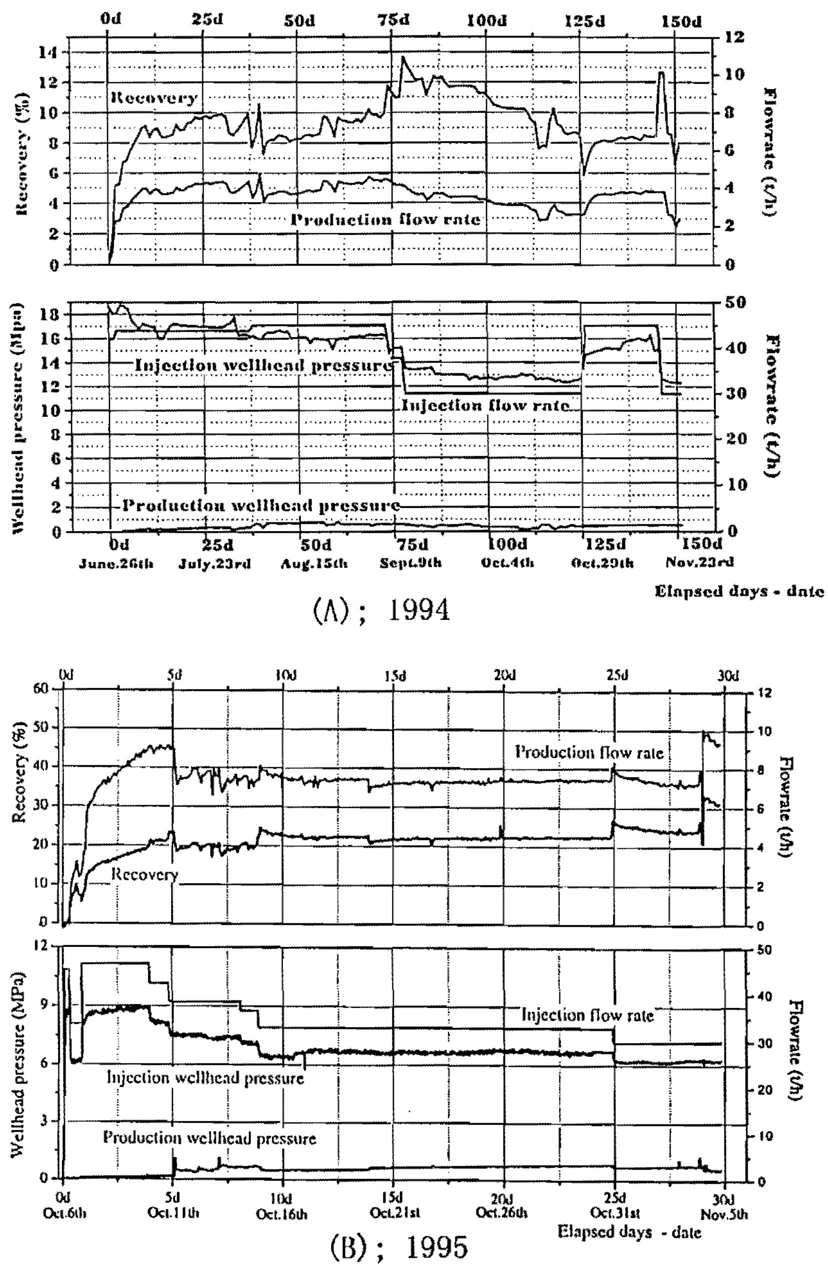

Fig.-5 HYDRAULIC CIRCULATION CONDITIONS

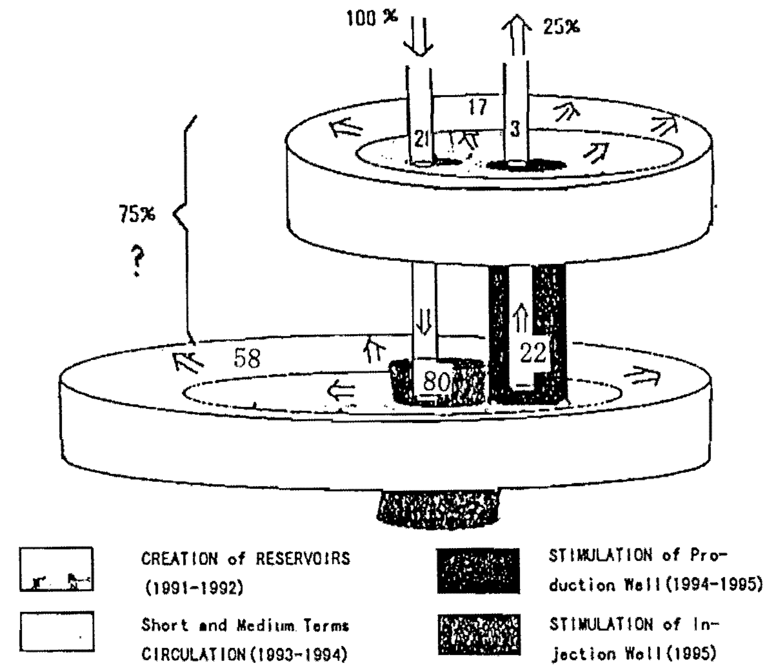

Fig-7. A CONCEPT OF WATER FLOW AT RESERVOIRS IN 1995

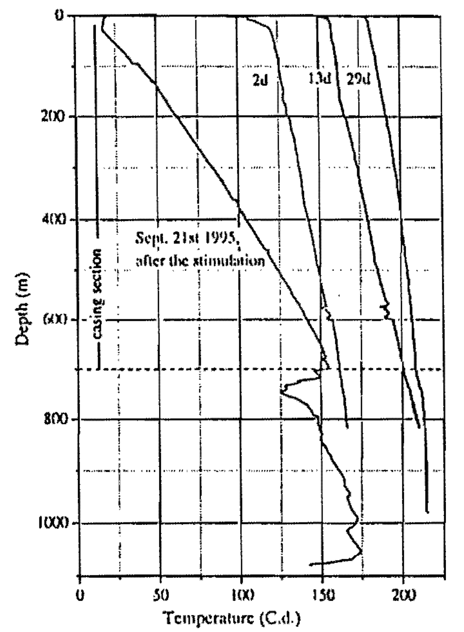

Fig-6 Temperature changes in the production well in 1995

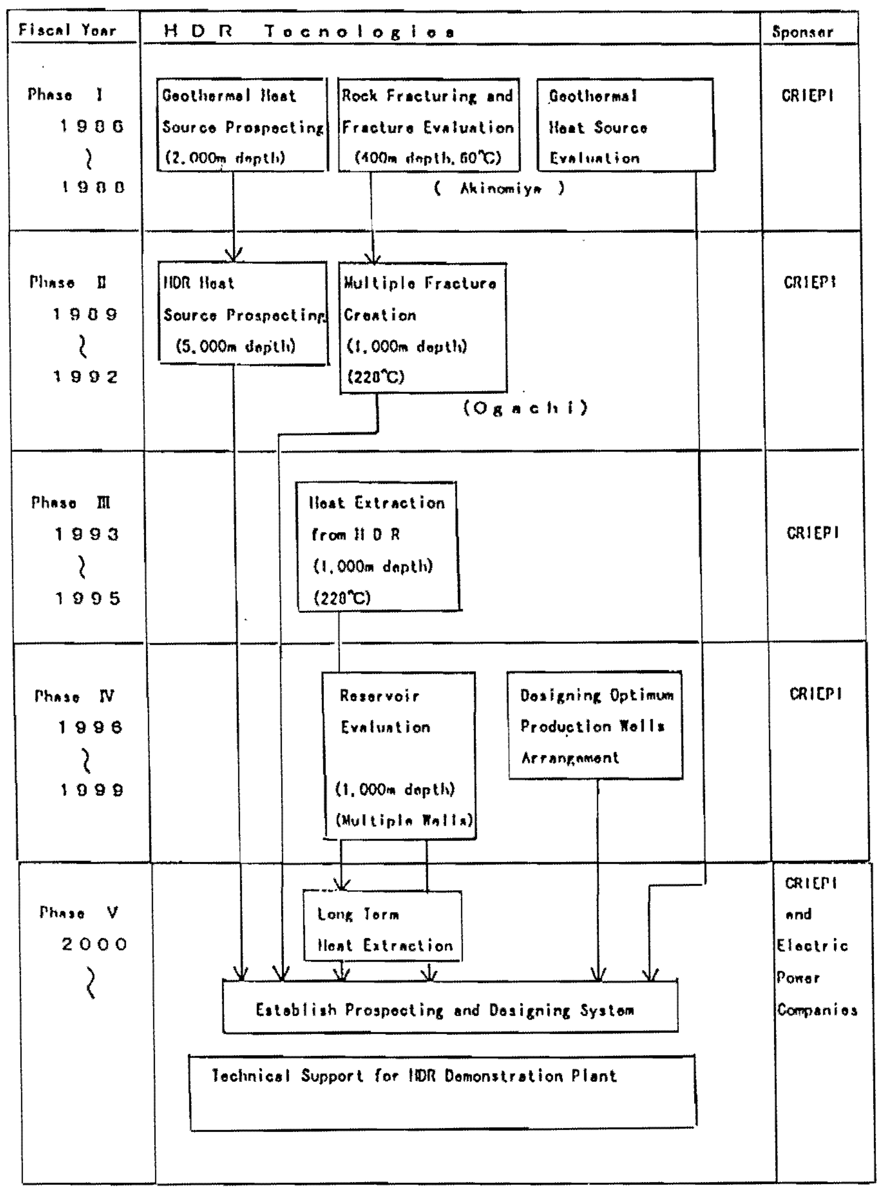

Fig-8. RESEARCH PLAN OF OGACHI PROJECT