# 附件 4 Keynote-2 超臨界條件案例-冰島深鑽計畫

## IDDP-2 - DRILLING INTO THE SUPERCRITICAL AT REYKJANES

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**Keywords:** *Supercritical geothermal fluid, deep drill holes, IDDP, DEEPEGS*

## ABSTRACT

The IDDP-2 well in Reykjanes, SW-Iceland, is the main topic of the presentation. The well was completed January 25th 2017 at 4659 m slant depth from rig floor. At Reykjanes, the landward extension of the Mid-Atlantic Ridge (Figure 1), it is possible to study an analog of the roots of a mid-ocean ridge black smoker geothermal system. Reykjanes is unique among Icelandic geothermal systems in being recharged by seawater, which has a critical point of 406°C at 298 bars. Drilling began 11th August, 2016 by deepening an existing 2.5 km deep production well (RN-15) to 3 km depth, and then angling it towards the main upflow zone of the system (Figure 2).

The Iceland Deep Drilling Project (IDDP) aims to improve geothermal economics by producing supercritical fluids (www.iddp.is ). Wells producing from supercritical hydrous fluid could yield an order of magnitude more usable energy than that from conventional geothermal wells because of higher enthalpy and enhanced flow properties. In 2009, the IDDP-1 well in the Krafla caldera in NE-Iceland, was drilled into rhyolitic magma at only 2.1 km depth. The completed well became the world's hottest production well for a while and produced superheated steam with wellhead temperature of 452°C at 140 bar, and flow sufficient to generate ~35 MWe. Flow testing experiments until 2012 proved extremely valuable for future harvesting of a magma enhanced geothermal system, which will also be discussed during the presentation.

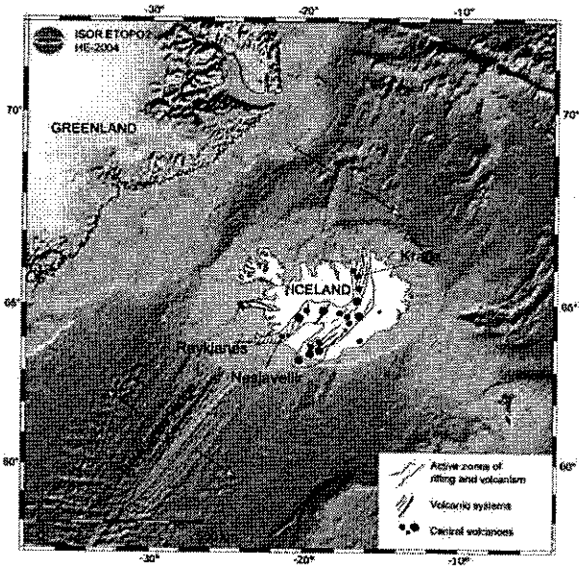

**Figure 1 The location of Iceland on the Mid-Atlantic Ridge. The arrows show the spreading directions. Iceland's neo-volcanic zone with its active central volcanoes, is also shown and the location of the three high-temperature hydrothermal systems of Reykjanes, Nesjavellir, and Krafla, all targets for IDDP deep drilling.**

In IDDP-2 at Reykjanes, total circulation losses were encountered so to speak from 2.5 km depth to the bottom of the well at 4650 m. After the 9 5/8" production casing had been cemented to 2,931 m depth, drill cuttings were intermittently returned to surface, but repeatedly interrupted by multiple loss of circulation, which could not be cured by lost circulation materials or by multiple cement jobs. Therefore, drilling had to be continued to total depth without any return of drill cuttings. We attempted 13 core runs below 3 km depth, only half of which recovered core. The cores are basalts and dolerites with alteration ranging from lower greenschist facies to lower amphibolite facies, suggesting formation temperatures >450°C. Close to the end of drilling, January 3d 2017, after inserting 7” casings (perforated liner to 4,570 m and a sacrificial casing to 1,300 m), and after only six days of heating, supercritical conditions (426°C at 340 bars) were measured in the well at a depth of 4.5 km (Figure 3). Drilling with 6” bits and coring tools continue through the perforated line to a depth of 4659 m, ending January 25th, 2017. Cold water stimulation is still ongoing, attempting to enhance the deep permeability. The well will not be allowed to equilibrate to full formation temperature until late 2017 and in 2018 it will be followed by a flow test and eventual production of the well.

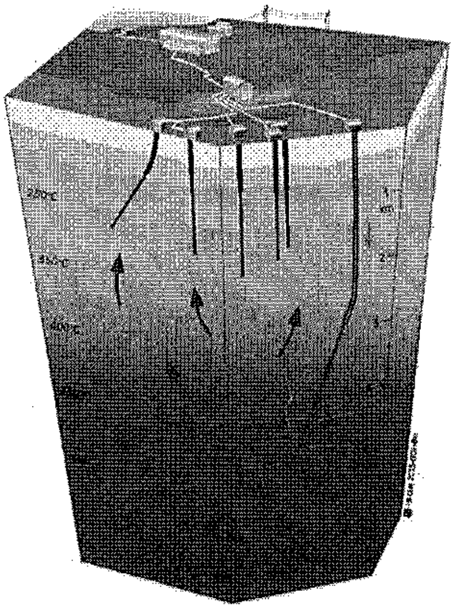

**Figure 2. Conceptual model of the roots of the Reykjanes Geothermal field indicating existing wells and the track of the IDDP-2 to intersect the supercritical zone.**

## ACKNOWLEDGEMENTS

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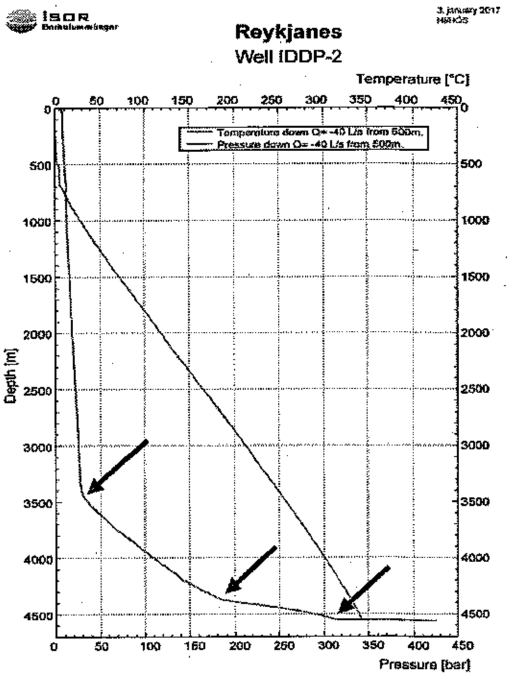

**Figure 3. Temperature and pressure log to 4,550 m depth in IDDP-2 after only 6 days of heating. Blue arrows indicate feed points.**

## REFERENCES (selected)

Friðleifsson, G.Ó., et al., 2017. The Iceland Deep Drilling Project 4.5 km deep well, IDDP-2, in the sea-water recharged Reykjanes geothermal field in SW Iceland has successfully reached its supercritical target. *Scientific Drilling, (in press)*

Friðleifsson, Elders and Bignall, 2013. A plan for a 5 km-deep borehole at Reykjanes, Iceland, into the root zone of a black smoker on land. *Scientific Drilling*, 16, 73-79.

附件 5 Keynote-3 發現探勘新地熱系統

# DISCOVERING NEW GEOTHERMAL SYSTEMS IN THE GREAT BASIN REGION, WESTERN USA: AN INTEGRATED APPROACH FOR ESTABLISHING GEOTHERMAL PLAY FAIRWAYS

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**Keywords:** *Geothermal exploration,* Nevada, *play fairway, structural controls, direct evidence.*

## ABSTRACT

The Great Basin of the western USA is capable of producing much greater amounts of geothermal energy than the current ~670 MW from ~25 power plants. Most geothermal resources in this region are blind, and thus the favorable characteristics for geothermal activity must be synthesized and methodologies developed to discover new commercial-grade systems (>130°C). The geothermal play fairway concept involves integration of multiple parameters indicative of geothermal activity as a means of identifying promising areas for new development. In the Nevada play fairway project, nine geologic, geochemical, and geophysical parameters were initially synthesized to produce a new geothermal potential map of 96,000 km$^2$. These parameters were grouped into subsets and individually weighted to delineate rankings for heat and local, intermediate, and regional permeability, which collectively defined the play fairways.

From the regional map, 24 highly prospective areas, including known undeveloped systems and unknown potential blind systems, were identified for further analysis. Five particularly promising sites were then selected for detailed studies. Multiple techniques, including geologic mapping, Quaternary fault analysis, 2-m temperature surveys, gravity surveys, LiDAR, geochemical studies, seismic reflection analysis, and 3D modeling, were employed in these areas to define likely sites for high permeability and define highly prospective drilling targets. Local and intermediate permeability models were revised to reflect results of detailed analyses and generate new detailed play fairway maps. Lessons learned include: 1) initially identified sites commonly include multiple favorable settings at a finer scale; 2) promising sites in Cenozoic basins cannot be recognized without detailed geophysical surveys; and 3) play fairway analysis is critical at multiple scales, providing a means to select regional prospects as well as vectoring into drilling targets at individual sites. Based on our detailed studies, several potential new, high temperature systems were discovered. However, TG drilling is needed to confirm commercial grade resources.

## 1. INTRODUCTION

The geothermal play fairway concept involves integration of multiple parameters indicative of geothermal activity as a means of identifying the most promising areas for new geothermal development (e.g. Faulds et al., 2016a,b; Shervais et al., 2016; Forson et al., 2016; Lautze et al., 2016; Wannamaker et al., 2016;). This includes the evaluation of the relative favorability of known, undeveloped geothermal systems, as well as assessing the probability of a particular area for hosting a heretofore undiscovered, blind relatively high-temperature (>130°C) system capable of generating electricity. In the first phase of this project, we applied the play fairway methodology across a broad swath (96,000 km$^2$) of the Great Basin of Nevada in the western USA, a well-exposed extensional to transtensional, active tectonic setting. Phase II involved detailed studies of five highly prospective areas defined by the play fairway analysis in phase I (Fig. 1).

The Great Basin region of Nevada and adjacent parts of neighboring states is a world-class geothermal province with over 670 MW of current capacity at ~25 operating power plants. Although geothermal production has been trending slowly upward in recent years, all studies indicate far greater potential for conventional hydrothermal systems in the region (e.g. Williams et al., 2007, 2009). The Great Basin lies within the Basin and Range province of western North America, a broad region of crustal extension that has been active since the Miocene. The geothermal wealth of this region can be attributed to its active extensional to transtensional setting, including the diffusion of ~20% of the Pacific-North American dextral plate motion (~1 cm/year) along the Walker Lane into extension (Faulds et al., 2004). Accordingly, strain rates increase to the northwest across Nevada from much less than 1 mm/year near the Utah border to ~1 cm/year in the Walker Lane belt (Kreemer et al., 2012). As such, Quaternary normal faults abound across the Great Basin and provide the most fundamental, first-order control on geothermal activity, with nearly all geothermal systems located proximal to Quaternary faults (Bell and Ramelli, 2007).

Most of the geothermal systems (>85%), especially the relatively high-temperature systems (>130°C), reside in fault interaction zones, such as fault terminations, fault intersections, fault step-overs or relay ramps, accommodation zones, and displacement transfer zones, as opposed to the main segments of range-front faults (Curewitz and Karson, 1997; Faulds et al., 2006, 2011; Faulds and Hinz, 2015). These fault interaction zones typically contain higher densities of faults, which enhance permeability and thus provide conduits for geothermal fluids. Most of the geothermal systems in the region are amagmatic and not associated with middle to upper crustal magma chambers.

Because most geothermal systems in the Great Basin are controlled by Quaternary normal faults, they generally reside near the margins of basins. Consequently, upwelling fluids along the faults commonly flow into permeable sediments in the subsurface and do not daylight directly along the fault. Outflow from these upwellings may therefore surface many kilometers away from the deeper source or remain entirely "blind" with no surface hot springs or steam vents (Richards and Blackwell, 2002; Coolbaugh et al., 2007). Thus, techniques are needed both to identify the major structural settings that enhance permeability and to determine which areas may currently channel hydrothermal fluids. The recent discovery in central Nevada of the robust geothermal system at McGinness Hills, a blind field that currently produces ~88 MW (Nordquist and Delwiche, 2013), suggests that many systems are yet to be discovered in the region. Application of the play fairway methodology therefore holds promise of yielding significant results.

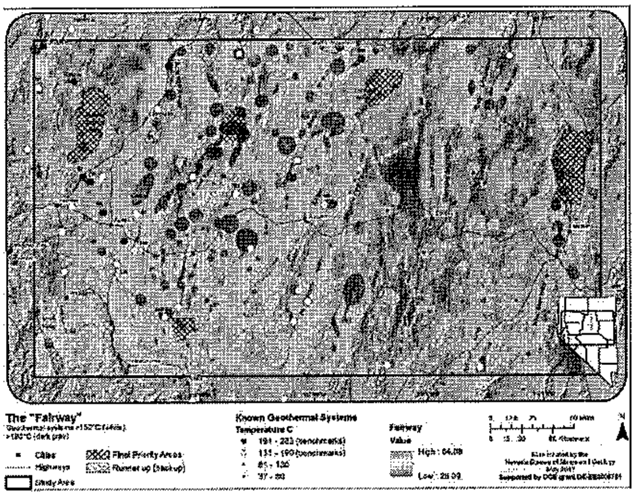

**Figure 1: Final down-select areas for detailed studies in phase II shown by black hachures overlain on the play fairway map produced in phase I. Runner-up areas are shown by light gray hachures. From west to east across the northern tier, detailed study areas are Granite Springs Valley, Sou Hills, Crescent Valley, and Steptoe Valley. The lone area in the southern part is southern Gabbs Valley. From north to south, runner-up areas are Dun Glen, Lovelock Meadows, southern west flank of the Humboldt Range, and Wellington.**

In phase I of this project, we developed a comprehensive, statistically based geothermal potential map for 96,000 km$^2$ across the Great Basin of Nevada (Fig. 1; Faulds et al., 2015a,b, 2016a,b). This transect extended from west-central to eastern Nevada in order to capture the major aforementioned strain gradient across the region. Further, the transect incorporates a major transition in basements rocks from primarily Mesozoic crystalline rocks (granitic and metamorphic rocks) in the west to dominantly Paleozoic carbonates and sediments in the east. This project focused on fault-controlled geothermal play fairways due to the affiliation of most geothermal systems in the region with Quaternary faults (Curewitz and Karson, 1997; Blackwell et al., 1999; Richards and Blackwell, 2002; Faulds et al., 2006, 2010, 2011, 2013; Hinz et al., 2011, 2013, 2014). Nine parameters were incorporated into the geothermal potential maps, including: 1) structural settings, 2) age of recent faulting, 3) slip rates on recent faults, 4) regional-scale strain rates, 5) slip and dilation tendency on faults, 6) earthquake density, 7) gravity gradients, 8) temperature at 3 km depth, and 9) geochemistry from springs and wells.

As described in previous contributions (Faulds et al., 2015b, 2016a,b), these parameters were grouped into key subsets to define regional permeability, intermediate-scale permeability, local permeability, and regional heat, which were then combined to define the fairway (Fig. 2). Additionally, the fairway model was integrated with direct evidence of heat from wells and geothermometers to delineate favorability for geothermal development. Results compared favorably against a group of 34 benchmark sites, representing systems in the region with temperatures ≥130°C (Fig. 3). Fairway values range from a low of ~28 to near 65, with the 34 high-temperature (≥130°C) benchmarks yielding an average of 51.4.

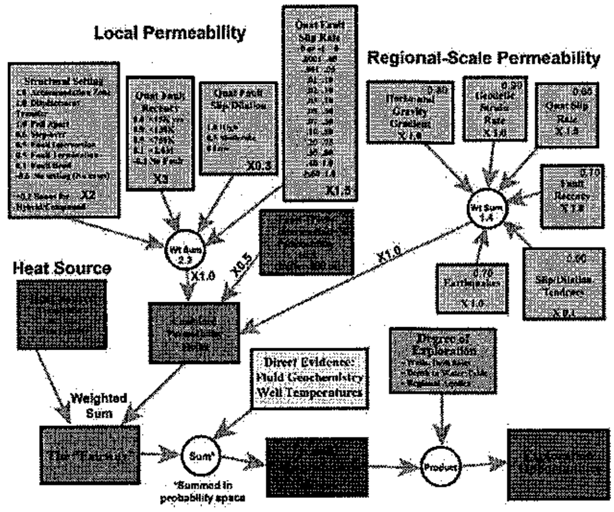

**Figure 2: Nevada play fairway modeling workflow (Faulds et al., 2016a). Red numbers indicate relative weights determined from weights of evidence. Black numbers indicate expert driven weights used in the analysis. In all cases, the expert driven weights took into account the statistical analyses.**

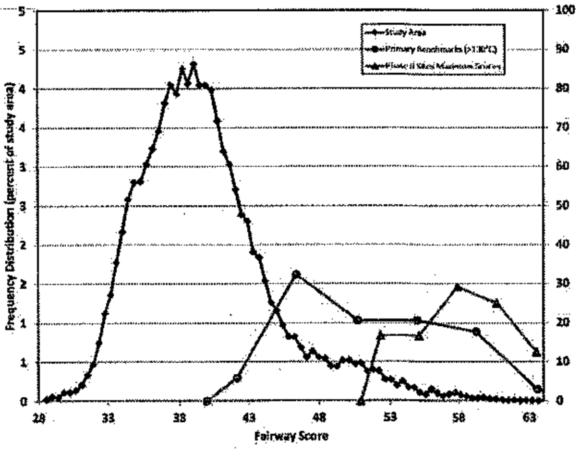

**Figure 3: Distribution of play fairway scores for the primary benchmark (>130°C) systems (red) compared to scores for the study area as a whole (blue) and the maximum values within the 24 highly prospective sites selected for analysis in phase II (purple) (Faulds et al., 2016a).**

## 2. DETAILED STUDY AREAS

Owing to the active extensional to transtensional tectonism and high heat flow in the Great Basin region, many sites in the broad study area (96,000 km$^2$) examined in phase I yielded high play fairway values. We chose 24 of the most promising sites for reconnaissance level assessment on the basis of the play fairway and favorability values, land status, and proximity to an established electrical transmission corridor. We then down-selected to five sites for detailed studies through a semi-quantitative analysis involving consideration of a) available geological, geochemical, and geophysical data, b) new shallow temperature and geochemical data collected in this study, c) land status including % of area considered primary sage grouse habitat, d) distance from an electrical transmission corridor, and e) degree of previous exploration. Due to the plethora of favorable sites in the region, we were able to bias our final selections to include broad geographical distribution that incorporates variations in tectonic setting (transtensional vs. purely extensional), strain rates, composition of basement rocks, and types of favorable structural settings. For example, the southern Gabbs Valley study area in west-central Nevada occupies a displacement transfer zone in a region of relatively high strain at the transition between the Walker Lane dextral shear zone and the extensional Basin and Range province, whereas Steptoe Valley 250 km to the east in eastern Nevada, contains a highly segmented Quaternary range-front fault with multiple step-overs in an area of relatively low, purely extensional strain. Granite Springs Valley in northwest Nevada was selected based on distinct horse-tailing terminations of a Quaternary range-front fault. Sou Hills in northern Nevada incorporates a major accommodation zone between oppositely dipping Quaternary normal fault systems in the relatively high strain central Nevada seismic belt (e.g. Caskey et al., 1996). Crescent Valley in north-central Nevada contains a major highly segmented range-front normal fault with several discrete step-overs and fault intersections in an area of modest extensional strain. Each study area contains several favorable structural settings and thus multiple potential geothermal targets that were evaluated with respect to one another to select the most highly prospective targets for drilling. Notably, the boundaries of all previously identified structural target areas were modified to reflect new details uncovered in phase II.

## 3. PLAY FAIRWAY ANALYSIS

Predictive play fairway maps were generated for each of the detailed study areas using the exploration data obtained during phase II studies (Faulds et al., 2017). These new data were integrated with the existing phase I database. The general methodologies for producing regional predictive maps in phase I (Faulds et al., 2015b) were followed in building detailed predictive maps in phase II. Modifications to the methodology were made to accommodate the introduction of new data types (e.g. 2-m temperature measurements, silica terrace mapping, and detailed temperature modeling) into the local permeability models.

Three main sets of predictive maps were generated. They are 1) play fairway maps, 2) play fairway error maps, and 3) direct evidence maps. Direct evidence maps are qualitative in nature, because probabilities are qualitatively assigned based on various types of evidence that consists principally of well and spring temperatures and geothermometers. Because of this qualitative aspect, direct evidence errors were not modeled in detail, but were assumed to equal a relative error of 25%, as was done in phase I. Two-meter temperature data, which are considered a form of direct evidence, are an exception; these errors were modeled in detail to ensure statistical significance.

The play fairway and direct evidence maps provide complementary information. The fairway maps highlight areas of geothermal favorability based on fundamental underlying geologic, geophysical, and geochemical data, whereas the direct evidence maps highlight areas of favorability based on "direct observations" of geothermal features, such as temperature anomalies, fluid geothermometer temperatures, temperature gradients, or the presence of surface geothermal features such as silica-cemented sands or sinter. In phase I, the fairway and direct evidence maps were combined to produce overall "favorability" maps. This was not done in phase II. Instead, it was found that because of the widely differing types of data employed in fairway and direct evidence maps, it was more informative to compare the results of both maps side by side to facilitate visualization of one or more conceptual models of three-dimensional fluid flow.

### 3.1 Model Methodologies

Modeling procedures for the five detailed study areas paralleled those of the phase I regional model (Faulds et al., 2015b). The regional-scale permeability and heat models of phase I remained unchanged, with the exception of the Steptoe Valley heat model, where additional data became available. In contrast, the local- and intermediate-scale permeability models were revised and updated to reflect results of detailed geologic mapping and geophysical and geochemical surveys. A number of adaptations and improvements were employed in the models to accommodate new types of data and additional structural attributes. These changes are briefly described below.

Structural Settings Quality Factor: A quality factor was introduced into the algorithm used to model the strength or quality of structural settings. This factor, scaled from 0 to 1, allows for a gradational membership of structural settings; that is, the degree to which a structural setting warrants inclusion in a local permeability model. Without such a quality factor, artificially abrupt boundaries between "structural settings" and "almost structural settings" can occur.

Magnetotelluric (MT) Data: In hydrothermal systems, strong low resistivity anomalies may correspond to clay caps above geothermal systems, whereas less intense but broader low resistivity anomalies correlate with geothermal reservoirs in some cases (Ussher, 2000; Cumming, 2009). MT data were only available for northern Granite Springs Valley. Because MT data were not available for the other study areas, MT was not included as a distinct parameter in the model. Instead, where present, we used low-resistivity anomalies to enhance the structural quality factor by 0.1.

Steptoe Valley Detailed Temperature Model: A temperature slice at a depth of 1250 m below sea level (bsl) from a detailed temperature model of Steptoe Valley was produced in this study and used to replace the regional temperature model used in phase I. Temperatures at that level correspond closely to a 3 km depth below the floor of Steptoe Valley, which is the depth used in Phase I. Because the range of temperatures in the phase I regional temperature model and the 1250-m bsl UGS model are similar, the same weighting parameters and methodologies used in phase I were also used in phase II to combine the heat model with the structural model to produce an overall play fairway model. The benefits of the new temperature model include a more accurate and detailed representation of temperatures, and an increased confidence in the model that results from significantly reduced errors (uncertainty). The availability of the temperature model also made it possible to produce more accurate estimates of temperature anomalies in wells, which are used for input into the direct evidence model. A temperature anomaly at a given depth in a well was calculated by subtracting the predicted temperature from the model from the observed.

Two-meter temperature anomalies: A 2-m temperature survey was used to identify a significant anomaly in the southern Gabbs Valley area. The temperature data were converted to "degrees above background" (DAB) (e.g. Sladek and Coolbaugh, 2013). Three sources of error in the anomaly are recognized, each with a magnitude of ~1°C. These errors derive from 1) errors in measurement of temperature and depth, 2) errors in estimating background temperature, and 3) variations in subsurface temperatures caused by differences in surface albedo, topographic slope aspect, ground moisture, and elevation. A statistical test of significance was created using an inverse-distance-weighted temperature anomaly map divided by the estimated error, which showed that the central part of the anomaly is statistically significant. Additional confidence is provided by the spatial continuity of the DAB pattern, which does not fit any other observed phenomena, lending further credence to a geothermal origin.

A probability of occurrence of a 130°C geothermal system was assigned to the 2-m temperature anomaly as follows: a DAB of <2°C = 0 probability, 2-3°C = 0.15 probability, 3-4°C = 0.25 probability, 4-5°C=0.40 probability, and 5-6°C = 0.45 probability. These probabilities were assigned based on experience with these surveys, taking into account that temperatures of geothermal fluids at depth are unknown.

Sinter/silica-cemented sands and explosion craters: A newly recognized area of silica-cemented sands and sinter in Granite Springs Valley provides direct evidence of geothermal activity. The opaline material occurs as matrix silica surrounded by quartz sand grains. Based on the known association of opaline terraces with active geothermal systems, we assigned a probability of 0.6 to a 2-km buffer around this silica deposit. Two craters believed to have formed from hydrothermal explosions occur in the southwest corner of the Granite Springs study area (eastern Truckee Range). These craters were modeled with a 0.5 probability of association with 130°+C geothermal activity. No carbonate rocks or other formations susceptible to dissolution are known in the subsurface in this area.

### 3.1 Model Results: Ranking and Down-selection of Final Areas for Drilling

The fairway models of the five detailed areas have scores similar to those in the original phase I model. The major difference between the detailed phase II models and the phase I regional model is that locations of higher favorability are more accurately shown in the phase II models and at a higher level of detail. Figure 4 shows an example from southern Gabbs Valley. An error analysis shows that all potential targets of interest have a statistically significant anomalous fairway score, as measured by the difference between the local score and the average score, divided by the estimated error (Faulds et al., 2017). We note that fairway scores above ~45 indicate relatively high potential (Fig. 3).

Direct evidence maps are also more detailed than in phase I, because of the much greater availability of input data. This is most obvious at Gabbs Valley (Fig. 5), where very little direct evidence was available in phase I, and where phase II data strongly point to the existence of a previously unknown geothermal system. Similarly, at Granite Springs Valley Faulds et al., 2017), direct evidence in the form of surface silica deposits and anomalous well temperatures and geothermometry produce a coherent direct evidence pattern that is shifted northward relative to anomalous temperature gradient holes. In Steptoe Valley, a greater resolution of direct evidence in the form of temperature anomalies from springs and wells provides better resolution of possible outflow and/or upflow plumes related to known higher temperature springs and wells (Faulds et al., 2017).

Significant differences between phases I and II in the play fairway analysis are particularly strong for those study areas containing large late Cenozoic basins. New geophysical data in these areas afforded discovery of previously unrecognized intrabasinal, favorable structural settings, as exemplified in the Adobe Flat area of Granite Springs Valley and in the central part of southern Gabbs Valley (Fig. 4). These findings epitomize the importance of the detailed studies in refining exploration targets in such areas. Considering that nearly half of the Great Basin region is covered by basins, this also demonstrates the broad applicability of such detailed studies as well as the large untapped potential for commercial-grade geothermal systems in many of these basins.

It is important to reiterate that a primary difference between phase I and II of this project is that the regional analysis of phase I recognized relatively broad, favorable structural settings or clusters of settings in particular areas (Fig. 1). As is typical in any regional exploration program, it is difficult in the early stages to parse out the detailed characteristics of a particular area to select the most favorable targets for drilling. Upon more detailed analysis of individual areas in phase II, it became apparent that nearly all study areas contained multiple favorable structural settings. This presented the immediate challenge of applying our play fairway methodology at a finer scale to efficiently model the geothermal potential of each of the favorable settings within a particular study area. The detailed geological, geochemical, and geophysical investigations afforded such an analysis. Ultimately, we utilized the play fairway score to compare favorable settings in each of the study areas to one another and rank such areas to select the most promising sites for drilling. Thus, we found that our play fairway methodology was very adaptable to the natural evolution of an exploration program as it progresses from a regional analysis and vectors into the most promising prospects that present the lowest risk for development.

Although the play fairway scores are a key factor in selecting the most promising sites for drilling, several other factors must also be considered for selecting sites for drilling, including presence or absence of direct evidence (e.g. thermal anomalies, hydrothermal deposits, and geothermometry), land status, and accessibility. Distance to existing electrical transmission corridors is also important for potential development, but all detailed study areas already satisfied the minimum criteria in this regard (i.e. within 20 km of such a corridor) based on our earlier down-select criteria.

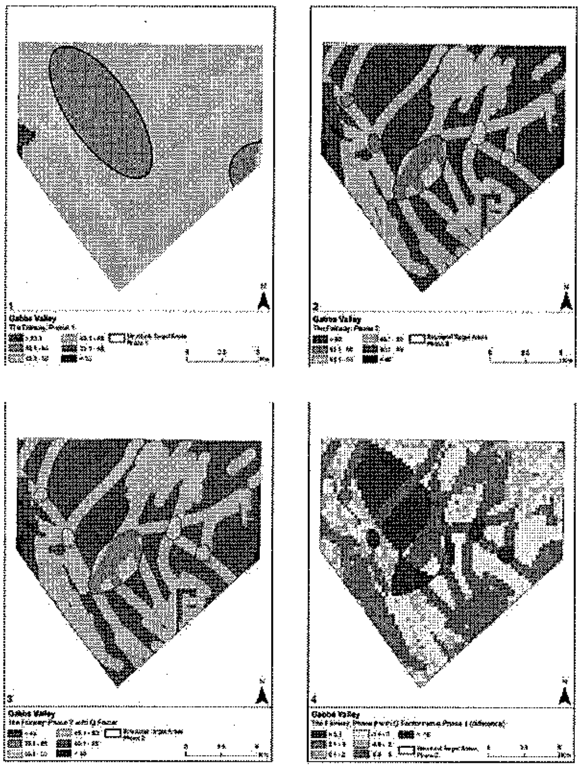

**Figure 4: Comparison of phase I and II fairway analysis for southern Gabbs Valley. Phase I fairway results (1). Phase II fairway results calculated the same as in Phase 1 (2). Fairway score from Phase II calculated with structural setting quality factor (3). Difference between the phase II and phase I fairway results (4) with positive numbers equal to increase of fairway score from phase I to phase II, and negative numbers equal to decrease in fairway score from phase I to phase II.**

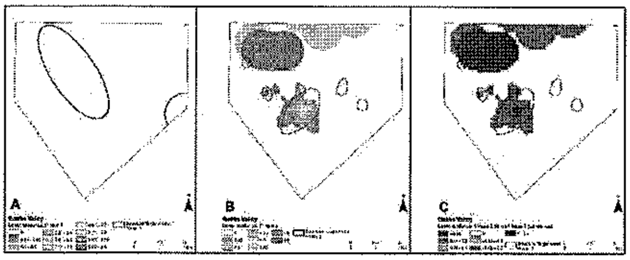

**Figure 5: Comparison of phase I and II direct evidence grid layers for southern Gabbs Valley. Phase I direct evidence (A). Phase II direct evidence (B). Difference between the phase II and phase I direct evidence modeling grid layer (C) with positive numbers equal to increase of fairway score from phase I to phase II.**

## 4. CONCLUSION

The results in phase II, including newly discovered hydrothermal features, shallow-temperature anomalies, and geothermometers indicative of commercial-grade temperatures of >130°C in all 5 study areas, have essentially validated our play fairway methodology. However, a critical test is whether our methodology can successfully target geothermal reservoirs with sufficient temperatures and volumes to support electrical generation. Therefore, the primary goal of phase III of this project is to complete the testing of our play fairway methodology through several closely integrated tasks that will characterize the temperature and geometry of each resource and provide a platform for evaluating commercial viability. These tasks include: 1) drilling TG holes to define the size of the thermal anomaly and identify possible up-flow zones; 2) collecting and analyzing new fluid samples directly associated with each resource to better define the reservoir temperature and provide direct context for the TG results; 3) collecting detailed potential field geophysics (gravity and magnetics) for building detailed 3D geologic models of each structural target area; 4) integrating potential field geophysics with existing phase II data and new drill data to build or update existing 3D geologic models; 5) collecting MT data to use with the 3D geologic model and temperature data to help build conceptual models of each reservoir and provide a clear road map for targeting deep geothermal wells by industry; and 6) integrating all data to develop conceptual models of the geothermal resources, identify and rank deep drilling targets, provide estimates of resource size, and present the phase III results in context of the play fairway analysis.

## ACKNOWLEDGEMENTS

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## REFERENCES

Bell, J.W., and Ramelli, A.R., 2009, Active fault controls at high-temperature geothermal sites: Prospecting for new faults: Geothermal Resources Council Transactions, v. 33, p. 425–429.

Blackwell, D., Wisian K, Benoit D, Gollan B., 1999, Structure of the Dixie Valley Geothermal System, a "Typical" Basin and Range Geothermal system, From Thermal and Gravity Data: Geothermal Resources Council Transactions, v. 23, p. 525-531.

Caskey, S.J., Wesnousky, S.G, Zhang, P., and Slemmons, D.B., 1996, Surface faulting of the 1954 Fairview Peak (Ms 7.2) and Dixie Valley (Ms 6.8) earthquakes, central Nevada: Bulletin of the Seismological Society of America, v. 86, no. 3, p. 761-787.

Coolbaugh, M.F., Raines, G.L., and Zehner, R.E., 2007, Assessment of exploration bias in data-driven predictive models and the estimation of undiscovered resources: Natural Resources Research, v. 16, no. 2, p. 199-207.

Coolbaugh, M., Sladek, C., Zehner, R., and Kratt, C., 2014. Shallow temperature surveys for geothermal exploration in the Great Basin, USA, and estimation of shallow aquifer heat loss: Geothermal Resources Council Transactions, v. 38, p. 115-122.

Cumming, W., 2009, Geothermal resource conceptual models using surface exploration data: Proceedings: 34th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, 6 p.

Curewitz, D. and Karson, J.A., 1997, Structural settings of hydrothermal outflow: fracture permeability maintained by fault propagation and interaction: Journal of Volcanology and Geothermal Research, v. 79, p. 149-168.

Faulds, J.E., Coolbaugh, M., Blewitt, G., and Henry, C.D., 2004, Why is Nevada in hot water? Structural controls and tectonic model of geothermal systems in the northwestern Great Basin: Geothermal Resources Council Transactions, p. 649-654.

Faulds, J.E., Coolbaugh, M.F., Vice G.S., and Edwards, M.L., 2006, Characterizing structural controls of geothermal fields in the northwestern Great Basin: A progress report: Geothermal Resources Council Transactions, v. 30, p. 69-76.

Faulds, J.E., Coolbaugh, M.F., Benoit, D., Oppliger, G., Perkins, M., Moeck, I., and Drakos, P., 2010, Structural controls of geothermal activity in the northern Hot Springs Mountains, western Nevada: The tale of three geothermal systems (Brady's, Desert Perk, and Desert Queen): Geothermal Resources Council Transactions, v. 34, p. 675-683.

Faulds, J.E., Coolbaugh, M.F., Hinz, N.H., Cashman, P.H., and Kratt, C., Dering, G., Edwards, J., Mayhew, B., and McLachlan, H., 2011, Assessment of favorable structural settings of geothermal systems in the Great Basin, western USA: Geothermal Resources Council Transactions, v. 35, p. 777-784.

Faulds, J.E., Hinz, N.H., Dering, G.M., Drew, D.L., 2013, The hybrid model – the most accommodating structural setting for geothermal power generation in the Great Basin, western USA: Geothermal Resources Council Transactions, v. 37, p. 3-10.

Faulds, N.H., and Hinz, N.H., 2015, Favorable tectonic and structural settings of geothermal settings in the Great Basin Region, western USA: Proxies for discovering blind geothermal systems: Proceedings, World Geothermal Congress 2015, Melbourne, Australia, 6 p.

Faulds, J.E., Hinz, N.H., Coolbaugh, M.F., Shevenell, L.A., Siler, D.L., dePolo, C.M., Hammond, W.C., Kreemer, C., Oppliger, G., Wannamaker, P.E., Queen, J.H., and Visser, C.F., 2015a, Integrated geologic and geophysical approach for establishing geothermal play fairways and discovering blind geothermal systems in the Great Basin region, western USA: A progress report: Geothermal Resources Council Transactions, v. 39, p. 691-700.

Faulds, J.E., Hinz, N.H., Coolbaugh, M.F., Shevenell, L.A., Siler, D.L., dePolo, C.M., Hammond, W.C., Kreemer, C., Oppliger, G., Wannamaker, P.E., Queen, J.H., and Visser, C.F., 2015b, Discovering blind geothermal systems in the Great Basin region: An integrated geologic and geophysical approach for establishing geothermal play fairways: Final report submitted to the Department of Energy (DE-EE0006731), 106 p.

Faulds, J. E., Hinz, N.H., Coolbaugh, M. F., Shevenell, L. A., and Siler D. L, 2016a, The Nevada play fairway project — Phase II: Initial search for new viable geothermal systems in the Great Basin region, western USA: Geothermal Resources Council Transactions, v. 40, p. 535-540.

Faulds, J.E., Hinz, N.H., Coolbaugh, M.F., Siler, D.L., Shevenell, L.A., Queen, J.H., dePolo, C.M., Hammond, W.C., and Kreemer, C., 2016b, Discovering geothermal systems in the Great Basin region: an integrated geologic, geochemical, and geophysical approach for establishing geothermal play fairways: Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, 15 p.

Faulds, J.E., Hinz, N.H., Coolbaugh, M.F., Shevenell, L.A., Siler, D.L., Sadowski, A., Ramelli, A.R.., McConville, E., Craig, J., and Queen, J.H., 2017, Discovering blind geothermal systems in the Great Basin region: An integrated geologic and geophysical approach for establishing geothermal play fairways: Budget Period 2: Final report submitted to the Department of Energy (DE-EE0006731), 37 p (and Appendices).

Forson, C., J. L. Czajkowski, D. K. Norman, M. W. Swyer, T. T. Cladouhos, and N. Davatzes: Summary of phase 1 and plans for phase 2 of the Washington state geothermal play-fairway analysis, *Geothermal Resources Council Transactions*, 40, (2016), 541-550.

Hinz, N.H., Faulds, J.E. and Stroup, C., 2011, Stratigraphic and structural framework of the Reese River geothermal area, Lander County, Nevada: A new conceptual structural model: Geothermal Resources Council Transactions, v. 35, p. 827-832.

Hinz, N., Faulds, J., Siler, D., 2013, Developing systematic workflow from field work to quantitative 3D modeling for successful exploration of structurally controlled geothermal systems: GRC Transactions, v. 37, p. 275-280.

Hinz, N.H., Faulds, J.E., Coolbaugh, M.F., 2014, Association of fault terminations with fluid flow in the Salt Wells geothermal field, Nevada, USA: Geothermal Resources Council Transactions, v. 38, p. 3–10.

Kreemer, C., Hammond, W.C., Blewitt, G., Holland, A.A., and Bennett, R.A., 2012, A geodetic strain rate model for the Pacific-North American plate boundary, western USA: NBMG Map 178, scale 1:1.500,000, 1 sheet.

Lautze, N., D. Thomas, G. Hill, E. Wallin, R. Whittier, S. Martel, G. Ito, N. Frazer, and N. Hinz: Phase 2 activities to improve a 2015 play fairway analysis of geothermal potential across the state of Hawaii, *Geothermal Resources Council Transactions*, 40, (2016), 559-566.

Nordquist, J., and Delwiche, B., 2013, The McGinness Hills geothermal project: Geothermal Resources Council Transactions, v. 37, p. 57-63.

Richards, M., and Blackwell, D., 2002, A difficult search: Why Basin and Range systems are hard to find: Geothermal Resources Council Bulletin, v. 31, p. 143-146.

Shervais, J.S., J.M. Glen, D. Nielson, S. Garg, P. Dobson, E. Gasperikova, E. Sonnenthal, C. Visser, L.M. Liberty, J. DeAngelo, D. Siler, J. Varriale, and J.P. Evans: Geothermal play fairway analysis of the Snake River Plain: Phase 1, *Proceedings,* 41st *Workshop on Geothermal Reservoir Engineering, Stanford University*, (2016), SGP-TR-209, 7 p.

Sladek, C., and Coolbaugh, M., 2013, Development of online map of 2 meter temperatures and methods for normalizing 2 meter temperature data for comparison and initial analysis: Geothermal Resources Council Transactions, v. 37, p. 333-336.

Ussher, G., 2000, Understanding the resistivities observed in geothermal systems: Proceedings: World Geothermal Congress 2000, Kyushu-Tohoku, Japan, May 28-June 10, 6 p.

Wannamaker P.E., K.L. Pankow, J.N. Moore, G.D. Nash, V. Maris, S.F. Simmons and C.L. Hardwick: Play fairway analysis for structurally controlled geothermal systems in the eastern Great Basin extensional regime, Utah, *Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University*, (2016), SGP-TR-209, 17 p.

Williams, C., Reed, M., Galanis, S.P., and DeAngelo, J., 2007, The USGS National Geothermal Resource Assessment: An Update: GRC Transactions, v. 31, p. 99-104.

Williams, C.F., Reed, M.J., DeAngelo, J., and Galanis, S.P. Jr., 2009, Quantifying the undiscovered geothermal resources of the United States: Geothermal Resources Council Transactions, v. 33, p. 995-1002.

附件 6 Keynote-4 未來地熱能創新與直接利用

# KAITIAKITANGA FUTURE GEOTHERMAL INNOVATION AND DIRECT USE

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## ABSTRACT

There are significant economic growth opportunities for both Māori and the wider New Zealand economy to work constructively together to realise the potential of natural resources. Taking a constructive and open approach to discussions on the use and development of these resources would lead to economic growth outcomes that are mutually beneficial to those that play a role as kaitiaki, Iwi Māori and all New Zealanders. Māori are interested in economic development opportunities and support a constructive discussion about the sustainable utilisation of natural resources.

The definition of kaitiakitanga should not be limited by the statutory definition, only tangata whenua can adequately define the nature and the role of a kaitiaki in respect of a particular resource. The tangata whenua of this region are Ngāti Tūwharetoa and Te Arawa who trace their descent from the common ancestor Ngātoroirangi of the Te Arawa waka. Calling his sisters Pupu and Te Hoata in Hawaiki bringing fire to his aid thus creating geothermal fields in development today. Many processes require this heat and can take advantage of geothermal energy to provide industry with an opportunity for a range of innovation and uses, depending on the temperature and sustainable extraction of the available geothermal fluid. Installations can be stand-alone, clustered or arranged in a cascading arrangement (e.g. a direct use application, after high temperature use for electric power generation), although developments may conversely cascade power generation off the direct use.

Māori are major stakeholders and contributors to economic growth in the regions, particularly in the central North Island, and the Māori economy has significant interests in many geothermal resources. Government targets pursue increased use of renewables and direct use of geothermal energy, as do local and regional economic development agencies. Māori is well-placed to meet some of these aspirations. This paper will explore kaitiakitanga, future geothermal innovation and direct use and show how Māori work best and most productively in collaboration – to develop scale in business and leverage existing resources.

## 1. INTRODUCTION

### 1.1 Te Whakatau O Ngātoroirangi

E Para E! Tikoko o te au marama
Tukua au kia puta ki tawhangawhanga nui no Rangi, no Papa
He aio; tu atu te makariri
Haramai te werawera
Hika ra taku ahi ki a Kautete tu
Hika ra taku ahi ki a Te Pupu
Hika ra taku ahi ki a Te Hoata
Ki a Te Moremore-o-te-rangi.

Māori consider themselves to be guardians of the environment, protecting and ensuring sustainable natural resources for future generations. Kaitiakitanga demonstrates the commitment Māori have to consider long-term sustainability of the resources and people impacted by any business decisions. Most of the traditions from Te Arawa, Tūwharetoa and Mataatua sources ascribe the origin of Geothermal activity in the Taupō Volcanic Zone to the exploits of Ngātoroirangi, and his sisters Kuiwai and Haungaroa aided by the atua Te Pupu and Te Hoata (Wilson et al., 2015).

Te Arawa, a confederation of tribes "Mai Maketu ki Tongariro," have held firm to their oral traditions passing these from generation to generation in perpetuity ensuring the continuation of their culture, their customs and the practice of ancient traditions through which they maintain a strong sense of spiritual connection to their spiritual homeland of Hawaiki. (Wilson et al., 2017).

One such narrative recants the indigenous world view of geothermal origins. A journey of exploration by Te Arawa ancestor Ngātoroirangi a Tohunga (high priest) born with a command of both physical and spiritual realms.

Ngātoroirangi was also navigator of the great voyaging waka Te Arawa, which made its final landfall at Okūrae (Maketu) in the Bay of Plenty where it remains to this day. (Wilson et al., 2017).

There is a clear correlation made in these traditions between the volcanic mountains and areas of surface geothermal activity, the hot springs, geysers, mud pools, sinter terraces and steam vents. Ngātoroirangi ascended Tongariro, where he almost perished, so intense was the cold on that mountain. Hence Ngātoroirangi called upon his ancestors to send heat and warmth to him, lest he perish. One of his vocations is shared above. (Wilson et al., 2017).

From the time of Ngātoroirangi, geothermal heat and energy have been considered taonga tuku iho (precious gifts provided by the gods) for our use. Te Arawa have since then utilised these for numerous domestic purposes and through trial and error discovered the different healing qualities ngāwhā (hot pools). This vast knowledge and routine of practices have become the traditional fabric which have defined these geothermal communities. (Wilson et al., 2017).

## 2. KAITIAKITANGA

In order to assist with consultation, local authorities are required to maintain, for each iwi and hapū within its region or district, a record of the contact details for each iwi authority, the planning documents recognised by each iwi authority, and the area over which iwi or hapū exercise kaitiakitanga. Section 35A Resource Management Act. As kaitiaki, this may include determining, for example, who should, or should not, have access to areas and resources, and how those things may or may not be utilised.

The Waiariki Māori Geothermal Advisory Group enables the ethic of kaitiakitanga through working with other industry groups and Māori to develop sector strategies. In order to overcome the existing barriers, we need to understand the costs and benefits that can be realised. Māori can participate in a productive conversation about the benefits and opportunities of sustainable development and use of these resources with all New Zealanders.

### 2.1 Māori and the RMA

RMA Principles - All persons exercising functions and powers under the Act are required to recognise and provide for seven matters of national importance set out in section 6. This includes:

- Section 6(e) the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, Wāhi tapu, and other taonga.
- Section 7 of the Resource Management Act sets out 'other matters' which persons exercising functions and powers under the Act must 'have particular regard to'. This includes section 7(a) kaitiakitanga.
- Section 8 requires that all persons exercising functions and powers under the Resource Management Act take into account the principles of the Treaty of Waitangi.

## 3. MĀTAURANGA MĀORI

Mātauranga Māori (Barlow 1993; Durie 1998; Harmsworth 1998; Harmsworth et al. 2002; Mead 2003; Waitangi Tribunal, 2011) provides the basis for the Māori world view and is a perspective encompassing all aspects of knowledge – e.g. philosophy, beliefs, language, methods, technology and practice. There are numerous definitions of mātauranga Māori. One of the more generally accepted is Marsden's (1988), which defines it, in a traditional context, as "the knowledge, comprehension or understanding of everything visible or invisible that exists across the universe'; this includes all Māori knowledge systems or ways of knowing and doing.

Ūkaipōtanga refers to the place where one is nurtured, where one finds their strength and their energy, grounding themselves to the land and home. It is recognition of origins, of treasured ancestral land passed down from generation to generation. They therefore have a sense of responsibility to care for and protect the place that passed on to them, as well as create the conditions for future generations to thrive. NZTE Māori Economy Investor Guide.

Māori are a tribally-based people. Each tribe (known as an iwi) is associated with specific geographical areas. Within these tribal groups are sub-tribes or smaller communities (known as hapū), which consist of a number of related families. The extended family unit is known as whānau. In Māori culture, land ownership and commercial activities can be undertaken both privately and collectively (as is also the case for other indigenous cultures around the world). The parent of the collective organisations will usually be a Trust (or occasionally an incorporated society). 'Māori land' owned by these collective organisations is recognised in legislation as a special category of asset, and is protected by specific legislation (NZTE Māori Economy Investor Guide, 2017).

With the majority of geothermal resources being on land controlled by Māori groups and trusts, collaboration is a driving force in the development of geothermal direct use opportunities (Richter, 2017).

## 4. GEOTHERMAL DIRECT USE

Geothermal power generation is an established industry in New Zealand, providing 1826 GWh electricity generation in the March 2017 Quarter (http://www.mbie.govt.nz/ info-services). Direct use of geothermal heat can make greater impact as it becomes an increasing part of New Zealand's geothermal energy portfolio (Hall and Climo, 2015; Carey et al., 2015). The Geoheat Strategy for Aotearoa New Zealand, 2017–2030 (see http://nzgeothermal.org.nz/geoheat/) was launched on 27 June 2017, with the New Zealand Geothermal Association (NZGA) being the strategy owner, and aims to double direct use of geothermal energy by 2030 and stimulate economic development using renewable energy solutions. The strategy provides a path for growing geothermal direct use in New Zealand, with a governance from industry, Maori and from the NZGA.

New Zealand uses ~7.5PJ of energy (per annum) from direct heat from geothermal resources, but the goal of the Geoheat Strategy is to build steadily towards 15PJ, as well as increasing new jobs. The view is that benefits will accrue by increasing understanding in industries, groups and individuals who do not currently fully appreciate the advantages of using a renewable geothermal source to meet their energy needs. Direct heat is already used widely for timber drying, in commercial scale glasshouses, for milk processing, tissue paper manufacturing, aquaculture, honey processing and bathing, and there are already many success stories in New Zealand, but also potential for increased uptake in the future.

At the forefront, is the possibility to increase direct use of geothermal energy by industries located near geothermal resources, who might be able to substitute non-geothermal based fuels. Many processes that require heat can use geothermal energy directly – although the temperature of the available geothermal fluid has to match the temperature required for the process. In this regard, understanding the character of the geothermal system, and its capacity to sustain development over many years, and minimise impact on the environment, is as important for direct use applications as it is for power generation.

A number of industrial scale applications exist in the forestry sector, which has a high demand for thermal energy for efficient timber drying, as well as creation of high value products from secondary timber processing, such as fibreboard, laminated timber, plywood and wood-plastic composites. Infusing plastic with wood fibre using geothermal direct heat to create a wood-plastic composite can be an effective alternative to preservative-treated wood, as the process helps to prevent water absorption. Agriculture is a primary industry of New Zealand, and this industry already has a strong track-record of using geothermal energy in production and processing, to heat, irrigate or sterilise soil, or to create microclimate in greenhouses to promote cultivation of fruit, vegetables or flowers, commonly using geothermal water of 60 – 80°C, whilst there is potential to enhance growth rates by redirecting geothermally-sourced $CO_2$ into a greenhouse. Aquaculture, applications for processing dairy and honey products and horticultural crops, also meat, leather and wool processing, and fish drying and fish oil processing can all use geothermal direct heat to meet their needs. Technologies are also being developed for converting biomass into biofuels – co-location of forestry and geothermal resources mean geothermal energy can be used to supply process heat for timber processing and paper manufacture, such as at Kawerau, with biomass residues put to high value use, such as for biofuel.

Figure 1 shows the total number of geothermal installations in New Zealand by their primary category. Where an installation fits into two or more categories, the primary category is the one that uses the most geothermal energy.

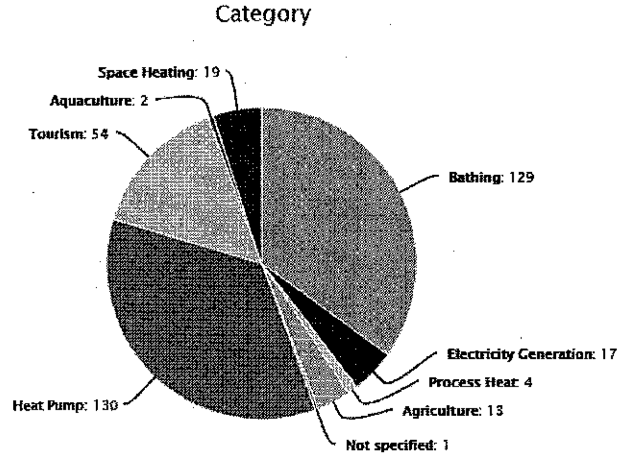

**Figure 1: Geothermal Use in New Zealand** (GNS Science, 2017)

The science of geothermal system delineation is well understood, and potential developers or users of geothermal resources in New Zealand are able to draw on many decades of experience and know-how to support their aspirations. Geophysical and chemical techniques to define the character of the geothermal systems were initially developed at Department of Scientific and Industrial Research (DSIR) in the 1960's onwards, whilst new geological framework modelling and numerical (resource capacity assessment and development scenario) modelling provides confidence resource exploration and development decisions can be made that reduce investment risk. Never the less, the decision to use geothermal energy can appear complex and/or confusing to those uncertain about resource exploration, characterisation, environmental issues, drilling, or the resource consent process. There are many success stories in New Zealand, as well as lessons learned, that should give potential developers confidence decisions concerning possible geothermal development can be made that reduce financial or development risk, mitigate possible effects, or identify early if an activity is not viable. The NZGA, GNS Science through its Government-funded research programme and outreach, existing New Zealand developers and consultants exist to facilitate geothermal developments that will have positive impact for iwi, and the Māori economy generally.

## 5. THE NEXT 10 YEARS AND BEYOUND

He kai kei aku ringa is the Crown-Māori Economic Growth Partnership and national Māori economic development strategy (He Kai Kei Aku Ringa, 2017). Established in 2012, it provides a vision for a productive, innovative, export oriented Māori economy driven by whānau. Literally it means 'providing food by my own hands'. It has become a metaphor for the resilience and economic self-determination of Māori people.

E RERE! heralds the next phase of He kai kei aku ringa where we take stock and reflect on the achievements of the Māori economic renaissance and turn to the future opportunities for the mighty Māori economy.

E RERE represents the five goals of He kai kei aku ringa

1. Employment – Whai Mahi – growing the future Māori workforce.
2. Rangatahi – supporting Māori youth to define and lead their economic aspirations.
3. Enterprise – Whai Pakihi- growing Māori enterprises.
4. Regions – Rohe Tū Pakari – increasing Māori participation in regional economies.
5. Education – Whai Mātauranga - upskilling the Māori workforce.

### 5.1 The Māori Economy

Ka tangi te tītī — The migratory bird that searches the globe for economic opportunities, it is connected to the home, but with a global view.

Ka tangi te kākā — The bird of the forest resources the domestic market.

The Māori economy is broadly defined as those privately owned and collectively-owned businesses that acknowledge their genealogical links to Māori ancestors. It currently represents $50 billion dollars in assets, which is approximately 6% of the total New Zealand asset base. Māori enterprises represent a rapidly growing segment of the wider New Zealand economy. They are poised to accelerate their rate of growth and increase their relative proportion of New Zealand's asset base and GDP. The New Zealand economy has been growing at 2-3% per annum and many of the key economic indicators for the Māori economy have been improving more rapidly than this at >5% per annum (including the growth in assets and incomes). This could result in the value of Māori assets growing from $50 billion to $100 billion by 2030. Māori are at the forefront of New Zealand's economic momentum.

### 5.2 Investment opportunities

It is expected that Māori will invest NZ$1.5 billion to NZ$2.0 billion per year over the next 10 years; and some of this investment will be enhanced through joint ventures and partnerships with other parties. The level of investment will range from venture funding ($1 million to $20 million), to significant initiatives requiring >$100 million and potentially up to $500 million, depending on the role of the investor. To date, Māori economic growth has centred around four main sectors with strong links to natural resources, land and culture. These include: agri-sector, forestry and fishing, tourism, property, construction and infrastructure, technology and innovation. These sectors are critical to the New Zealand economy, and to export growth in particular. Māori play a pivotal role in each since they control 50% of New Zealand's sustainable fishing quota, and own around 1.4 million hectares of land with significant opportunities for development.

### 5.3 Te Rautaki Māori - The GNS Science Māori Strategy

Creating mutual value by unlocking the potential of GNS Science-Māori relationships.

Mā tini, mā mano, ka rapa te whai by joining together we will succeed.

GNS Science's purpose is to undertake research that drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries, that develops industrial and environmental applications of nuclear science, that increases New Zealand's resilience to natural hazards and that enhances understanding of geological and earth-system processes. The economic and social benefits comprise: energy, mineral, and water wealth; protection of people and infrastructure from geological hazards; and new technologies for a transformed economy.

The Māori business strategy (Te Rautaki Umanga Māori – Te Rautaki) is an opportunity for GNS Science staff to think about Māori as client, collaborator, stakeholder, economic powerhouse, and business partner. GNS Science is committed to remaining at the forefront of the application of science for societal development. The creation of seamless relationships with Māori is a crucial element within this commitment (Hunter, 2017).

## 6. REGULATIONS

### 6.1 Māori and climate change mitigation

Many Māori support New Zealand joining with other countries to take measures to reduce emissions and mitigate the potential future effects of climate change (CCILG, 2016). Second, Māori have Treaty of Waitangi interests in the protection of their ancestral lands and waterways, and more broadly the natural environment, expressed in the values of kaitiakitanga. Kaitiakitanga "denotes the obligations of stewardship and protection … [and] is most often applied to the obligation of whānau, hapū and iwi to protect the spiritual wellbeing of natural resources within their mana" (New Zealand Law Commission, 2001).

### 6.2 Geothermal Energy Regulations 1961

The long awaited review of the Geothermal Regulations established in 1961 by the Ministry of Business Innovation & Employment (MBIE) is now underway.

## 7. CONCLUSIONS

As the Māori economy grows, Māori enterprises seek to build relationships with investment partners for mutual benefits. Māori enterprises have some special features, including a strong platform of cultural values, an intergenerational perspective on economic development and a particular focus on enduring relationships. Combined with the business acumen of Māori economic leaders, these special features provide unique entry points and opportunities for investors.

Māori values and culture play a vital part in both social and commercial activities. For the potential investor, having an understanding of these values is important for a number of reasons. These values are inherent in many aspects of the commercial relationships Māori organisations form with investors, customers, suppliers and external stakeholders. Recognising these values, and engaging with the culture, adds a dimension to the commercial relationship that is unique and valuable in its own right. The intention is to work co-operatively with those who have an interest in mātauranga Māori values to develop principled and practical solutions to issues that arise in the next 10 years in geothermal renewable energy.

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He kai kei aku ringa The Crown-Māori Economic Growth Partnership. Action Plan 2012-2017 Māori Economic Development Panel November 2012 pg 28.

NZ Geoheat Strategy for Aotearoa NZ 2017 - 2030 – Foreword Waiariki Māori Geothermal Advisory Group C/O Te Puni Kōkiri, Level 1 Te Puni Kōkiri House Rotorua 3046, New Zealand.

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## REFERENCES

Carey, B.; Dunstall, M.; McClintock, S.; White, B.; Bignall, G.; Luketina, K.; Robson, B.; Zarrouk, S.; Seward, A.: 2015 New Zealand Country Update: In. Proceedings World Geothermal Congress, Melbourne, Australia. 18p. (2015).

Climate Change Iwi Leadership Group, http://www.mfe.govt.nz/sites/default/files/media/NZETS_reviewstage1-Climate_Change_Iwi_Leaders_Group180.pdf, accessed 30 August 2017, (2017).

Climo, M.; Hall, J.; Coyle, F.; Seward, A.; Bendall, S.; Carey, B.: Direct Use: Opportunities and Development Initiatives in New Zealand. Proceedings World Geothermal Congress 2015, Melbourne, Australia, 19-25 April 2015. (2015).

GNS Science: Geothermal use database, https://data.gns.cri.nz/geothermal/charts.html, (accessed 30 August 2017), (2017).

Hall, J.; Climo, M.: Geothermal Direct Use in New Zealand: Industrial Heat Park Opportunities. GNS Science Report 2014/17. 36p. May 2015. (2015).

He Kai Kei Aku Ringa: E RERE Māori Economy Conference Videos and Presentations - 16 June 2017, Rotoruahttps://www.erere.maori.nz/erere-conference-material https://www.erere.maori.nz/ (2017).

Hunter, B.: Te Rautaki Maori The GNS Science Māori Strategy pg2. (2017).

Māori Economy Investor Guide 2017 p. 16 and 18. www.nzte.govt.nz. (2017).

Marsden M : The natural world and natural resources. Māori value systems and perspectives. Resource Management Law Reform Working paper 29. Part A. Wellington, Ministry for the Environment. (1988).

New Zealand Law Commission: Study Paper/Law Commission, Wellington, 2001 ISSN 1174–9776 ISBN 1–877187–64–X This study paper may be cited as: NZLC SP9. (2001).

Richter, A.: http://www.thinkgeoenergy.com (accessed on 30 August 2017), (2017).

Waitangi Tribunal: Ko Aotearoa Tenei: Report of the Waitangi Tribunal into claims concerning law and policy affecting Māori culture and identity (Wai 262). Wellington, Waitangi Tribunal. (2011).

Wilson, A.: Foreword. In: Climo, M.; Bendall, S.; Carey, B. 2017 Geoheat Strategy for Aotearoa NZ. 2017-2030. New Zealand Geothermal Association. (2017).

Wilson, A.; Nicholson, T.; Bignall, G.; Bradshaw, D: Kaitiakitanga and The Next 10,000 Megawatts NZGA Workshop, Wairakei, Taupō pg5. (2015).

Barlow, C.: Tikanga Whakaaro: Key concepts in Māori culture. Auckland, Oxford University Press 1993 (1993).

Durie, M.: Te mana, Te kawanatanga: The politics of Māori self-determination. Auckland, Oxford University Press. 280 p. (1998).

Harmsworth, G.R.: Indigenous values and GIS: A method and framework. Indigenous Knowledge and Development Monitor 6 (3): 3–7. http://app.iss.nl/ikdm/ikdm/ikdm/6-3/harmsw.html (1998).

Harmsworth, G.R.: Coordinated monitoring of New Zealand Wetlands, Phase 2, Goal 2: Māori environmental performance indicators for wetland condition and trend. Landcare Research Contract Report LC0102/099. Palmerston North, Manaaki Whenua – Landcare Research. 65 p. (2002).

mead, H.: Tikanga Māori: Living by Māori values. Wellington: Huia Publishers and Te Whare Wananga o Awanuiarangi. 398 p. (2002).

# 附件 7 MBIE 在地熱部門扮演之角色

**MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT**
HIKINA WHAKATUTUKI

## MBIE's Role in New Zealand's Geothermal Sector

**Working towards a transition to a low-carbon economy**

Alvin D'Almaida
Commercial Analysis and Investments
Energy Resource Markets

24 November 2017

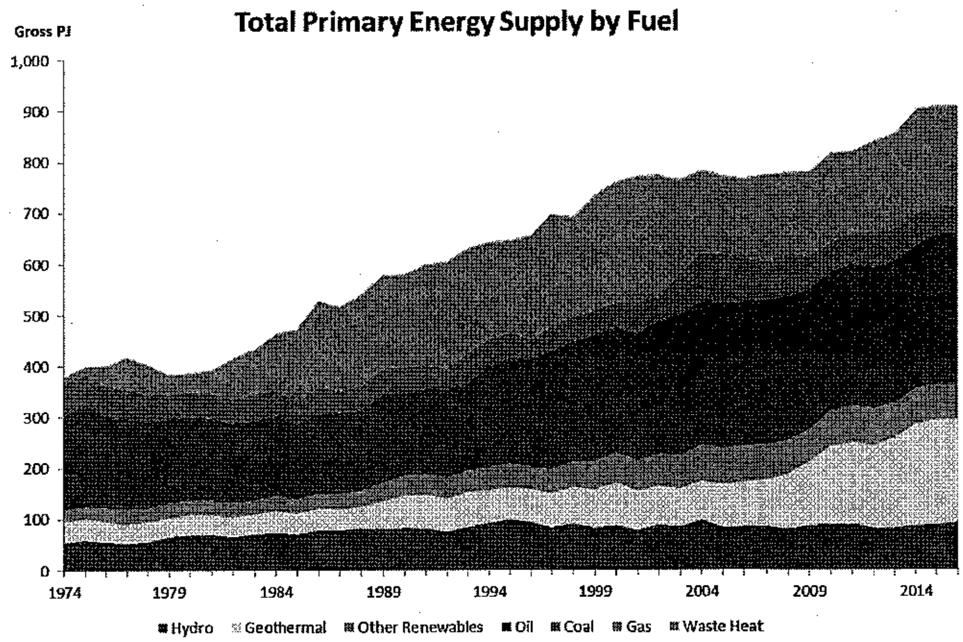
## The Government recognises the role of the geothermal sector in reducing carbon emissions

- Opportunity for New Zealand to be a market leader in geothermal energy economics
- Promotes regional growth via industry with a cheap and renewable energy alternative
- Fosters iwi, cross-agency and government-to-business stakeholder engagement


Transition to a low-carbon economy for New Zealand
Summary report
April 2016

# Geothermal energy is a major component of New Zealand's energy mix

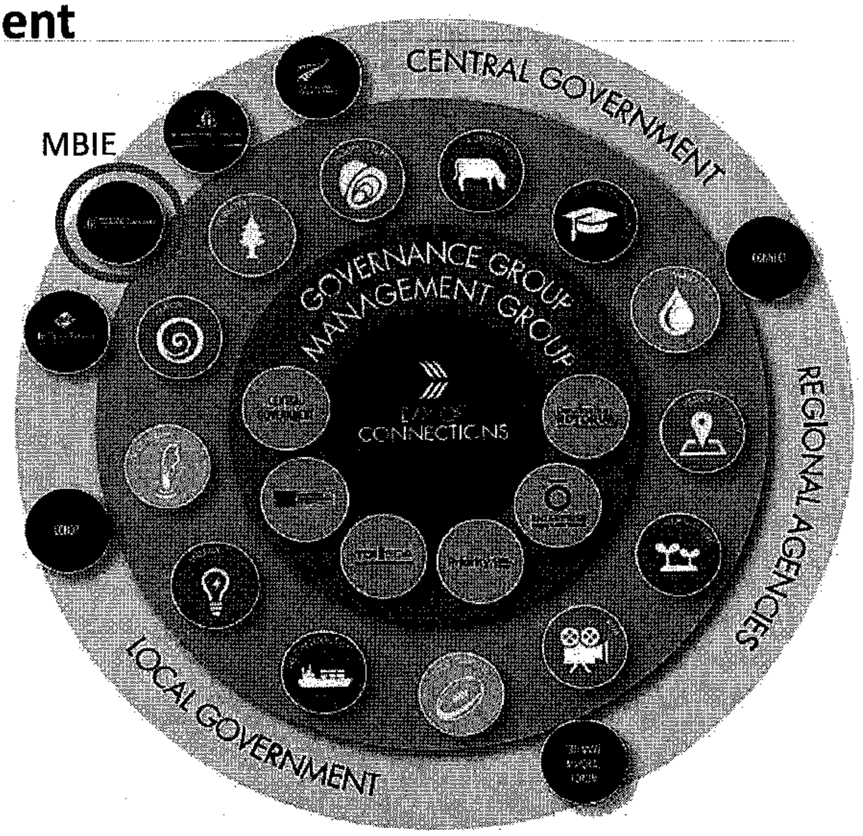
- MBIE is an active participant in New Zealand's transition to a low-carbon economy
- Energy in New Zealand 2017 Report*
- Geothermal power is a crucial part of New Zealand's overall energy mix
- And its importance is growing



*Source: http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/energy-in-new-zealand/documents-images/energy-in-nz-2017.pdf

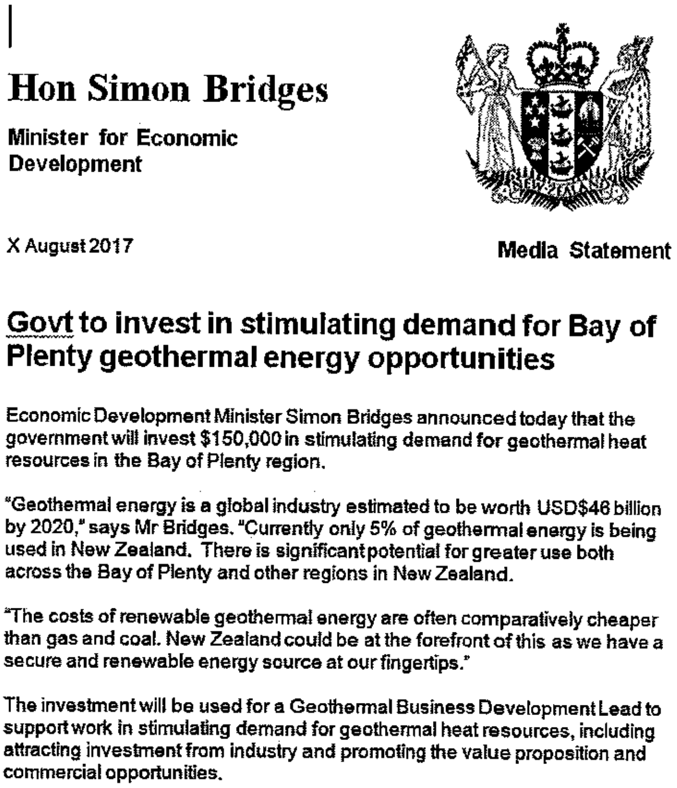
# MBIE recognises the importance of the geothermal sector to regional development

- Geothermal energy is a business enabler
- The sector is crucial to regional economic growth and development
- The Government is committed to partnering with regional business
- MBIE is a key partner in the Bay of Connections



# Core Funding

- One of four Central Government agencies supporting the Bay of Connections
- To investigate geothermal business development opportunities that utilise direct heat
- Stimulates Māori and regional economic development
- Fosters collaboration between different government agencies, private enterprise and iwi



**Hon Simon Bridges**

**Minister for Economic Development**

X August 2017

**Media Statement**

**Govt to invest in stimulating demand for Bay of Plenty geothermal energy opportunities**

Economic Development Minister Simon Bridges announced today that the government will invest $150,000 in stimulating demand for geothermal heat resources in the Bay of Plenty region.

"Geothermal energy is a global industry estimated to be worth USD$46 billion by 2020," says Mr Bridges. "Currently only 5% of geothermal energy is being used in New Zealand. There is significant potential for greater use both across the Bay of Plenty and other regions in New Zealand.

"The costs of renewable geothermal energy are often comparatively cheaper than gas and coal. New Zealand could be at the forefront of this as we have a secure and renewable energy source at our fingertips."

The investment will be used for a Geothermal Business Development Lead to support work in stimulating demand for geothermal heat resources, including attracting investment from industry and promoting the value proposition and commercial opportunities.

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# MBIE's role as an Investor
# Summary of the 2017 Endeavour Fund

Kennie Tsui
Contestable Investments
Science System Investment &Performance

24 November 2017

Home > Releases > Endeavour fund to invest $248m in research

**Paul Goldsmith** 13 SEPTEMBER, 2017

## Endeavour fund to invest $248m in research

Funding has been awarded for 68 new science research projects that will benefit New Zealand environmentally, economically, and socially, Science and Innovation Minister Paul Goldsmith announced today.

The funding, totalling $248 million over the next five years, has been invested through the Ministry of Business, Innovation and Employment's (MBIE) 2017 Endeavour Fund, which received an $81.9 million funding boost over four years in Budget 2017.

"The Endeavour Fund is an important tool in the Government's ten-year vision for a highly dynamic New Zealand science system," Mr Goldsmith says.

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# 2017 Endeavour Round Wrap Up

- **Increased funding due to Budget 2017**
  - Due to budget 2017, an increase of $10M per annum, a total of $58M per annum was invested.
  - Competition was high with median scores higher than 2016 in both Smart Ideas and Research Programmes.
  - This was split between Smart Ideas $15.4 M pa and Research Programmes $42.6M pa.

# Summary of 2017 Endeavour Round

## Success Rates:

| Number of Smart Ideas Concepts submitted | Number of Smart Ideas funded |
|---|---|
| 250 | 41 (16.4%) |

| Number of Research Programmes submitted | Number of Research Programmes funded |
|---|---|
| 158 | 27 (17.1%) |

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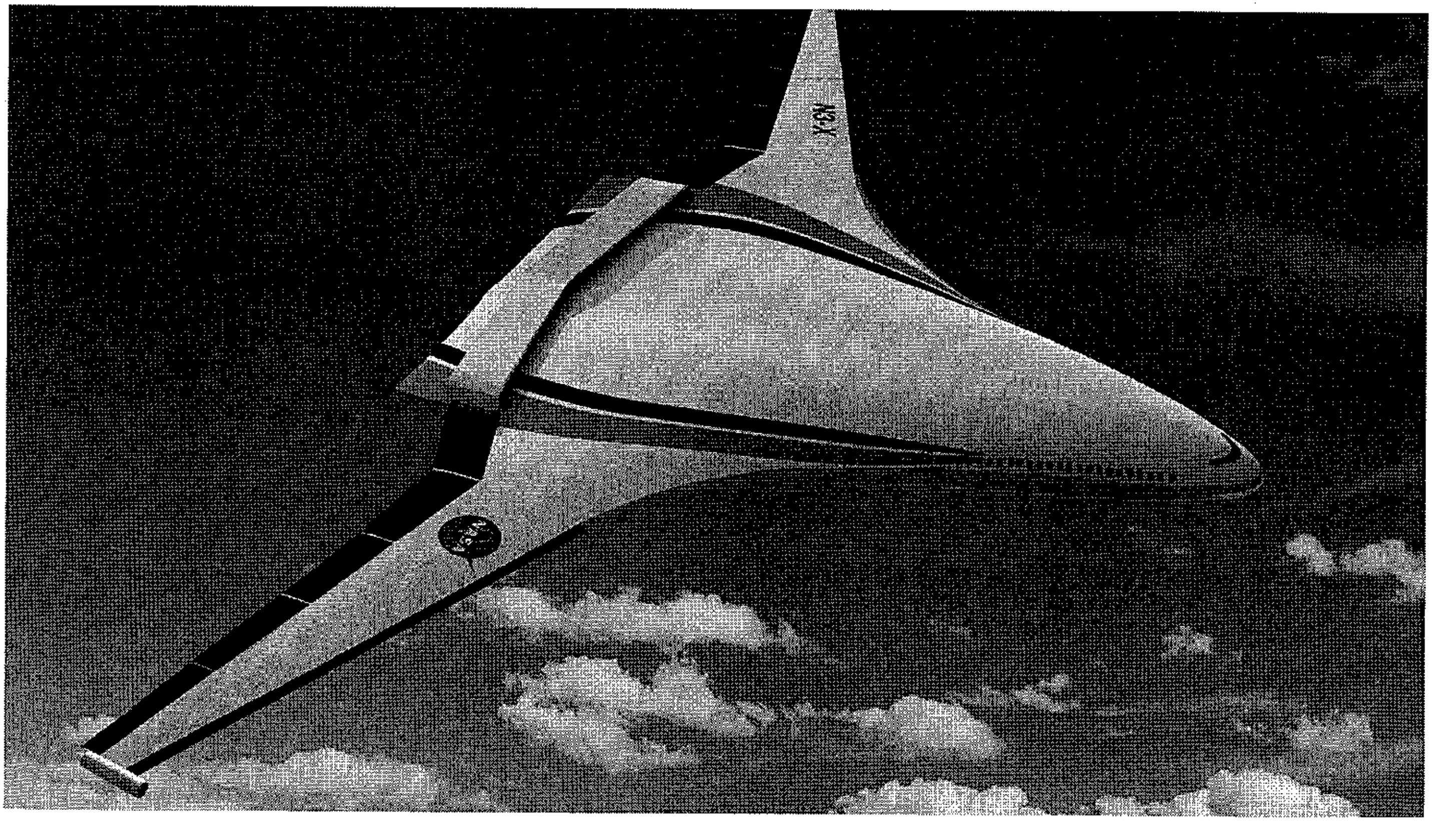
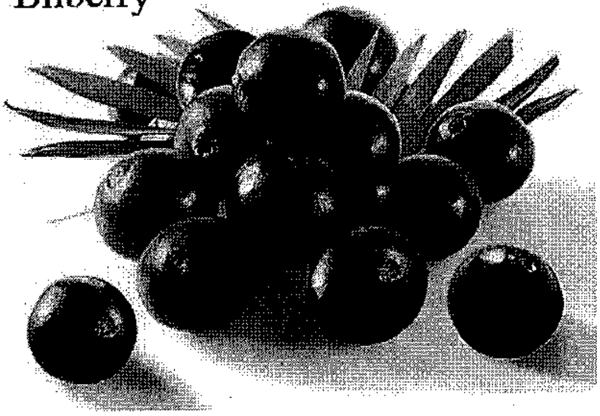
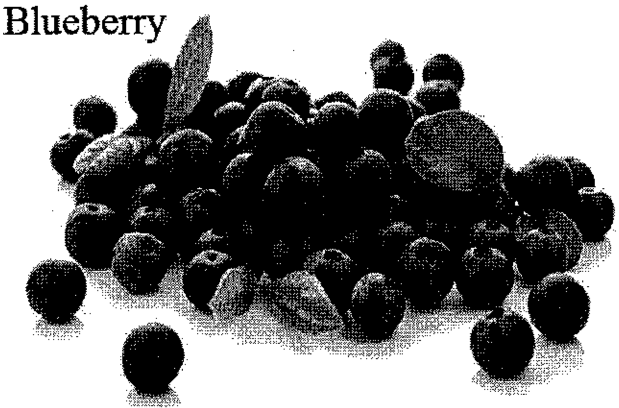
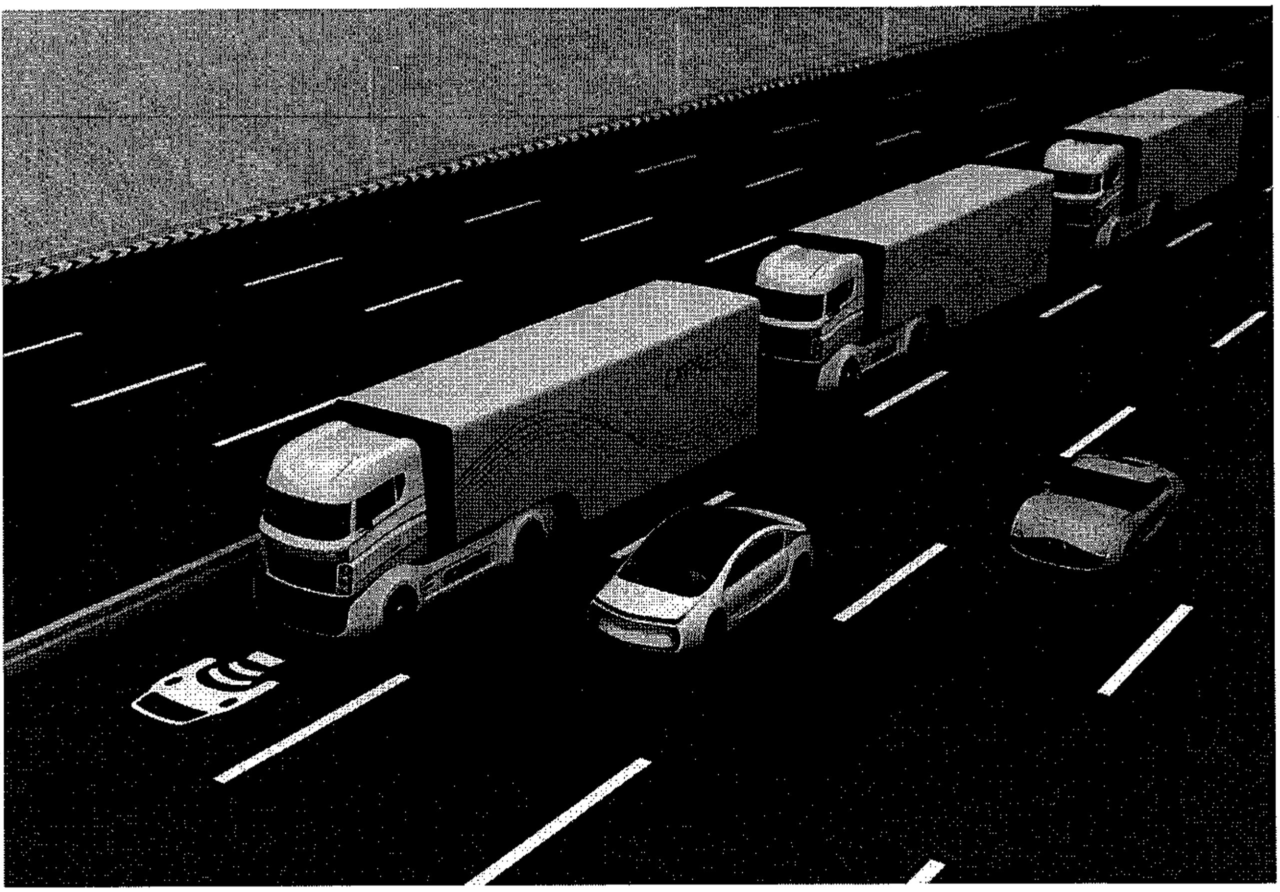


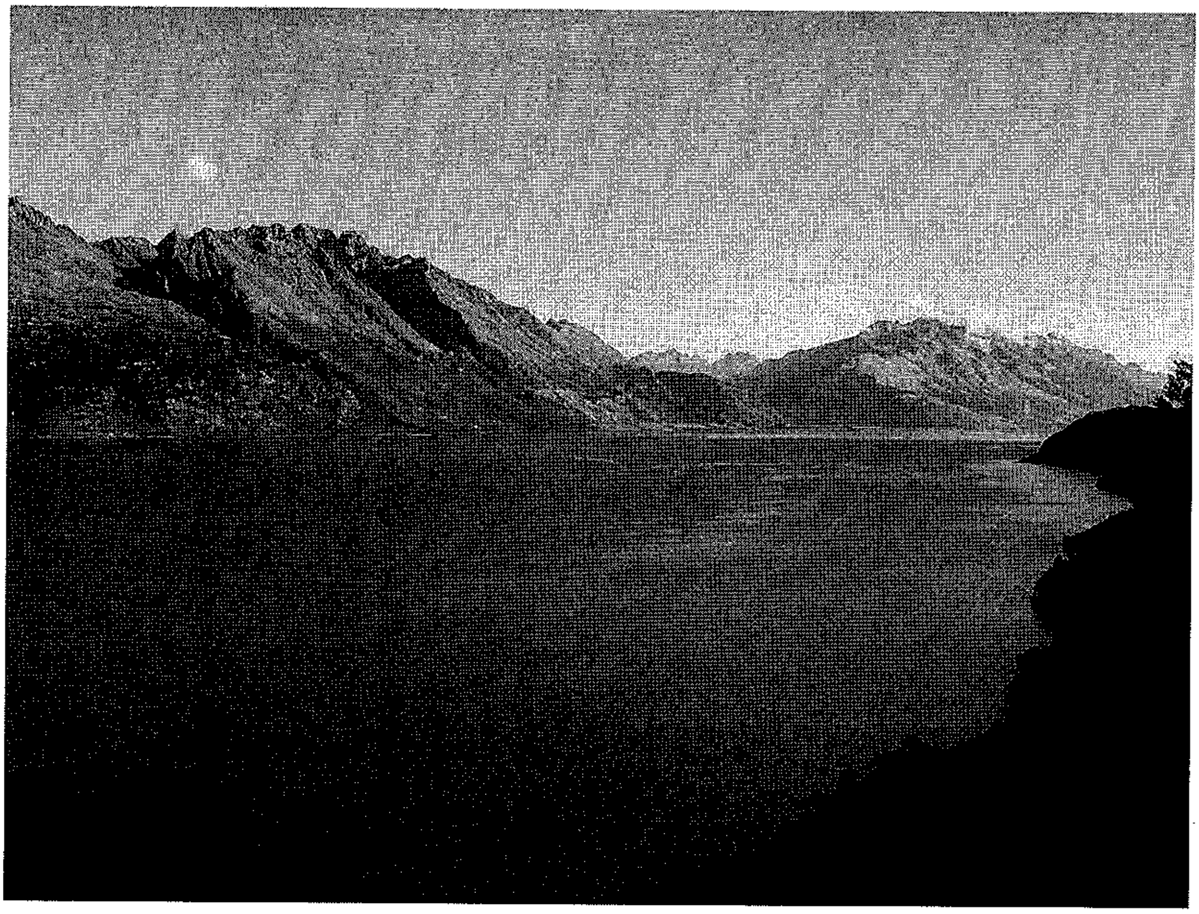
Bilberry



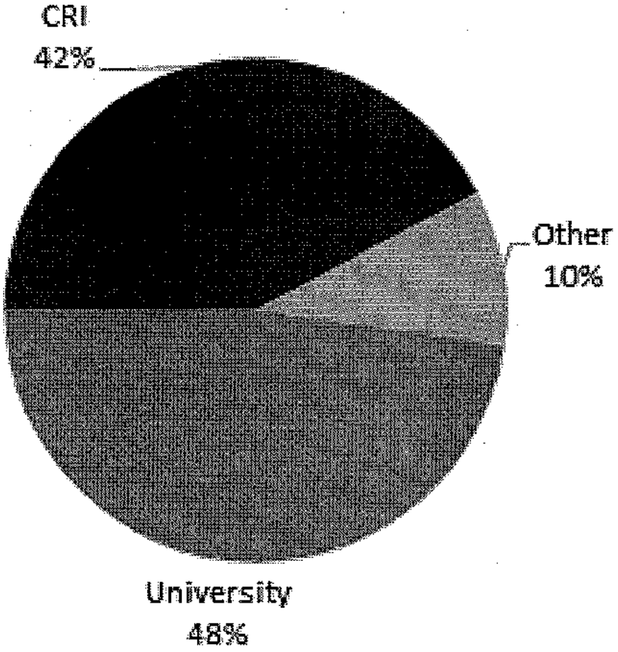
Blueberry

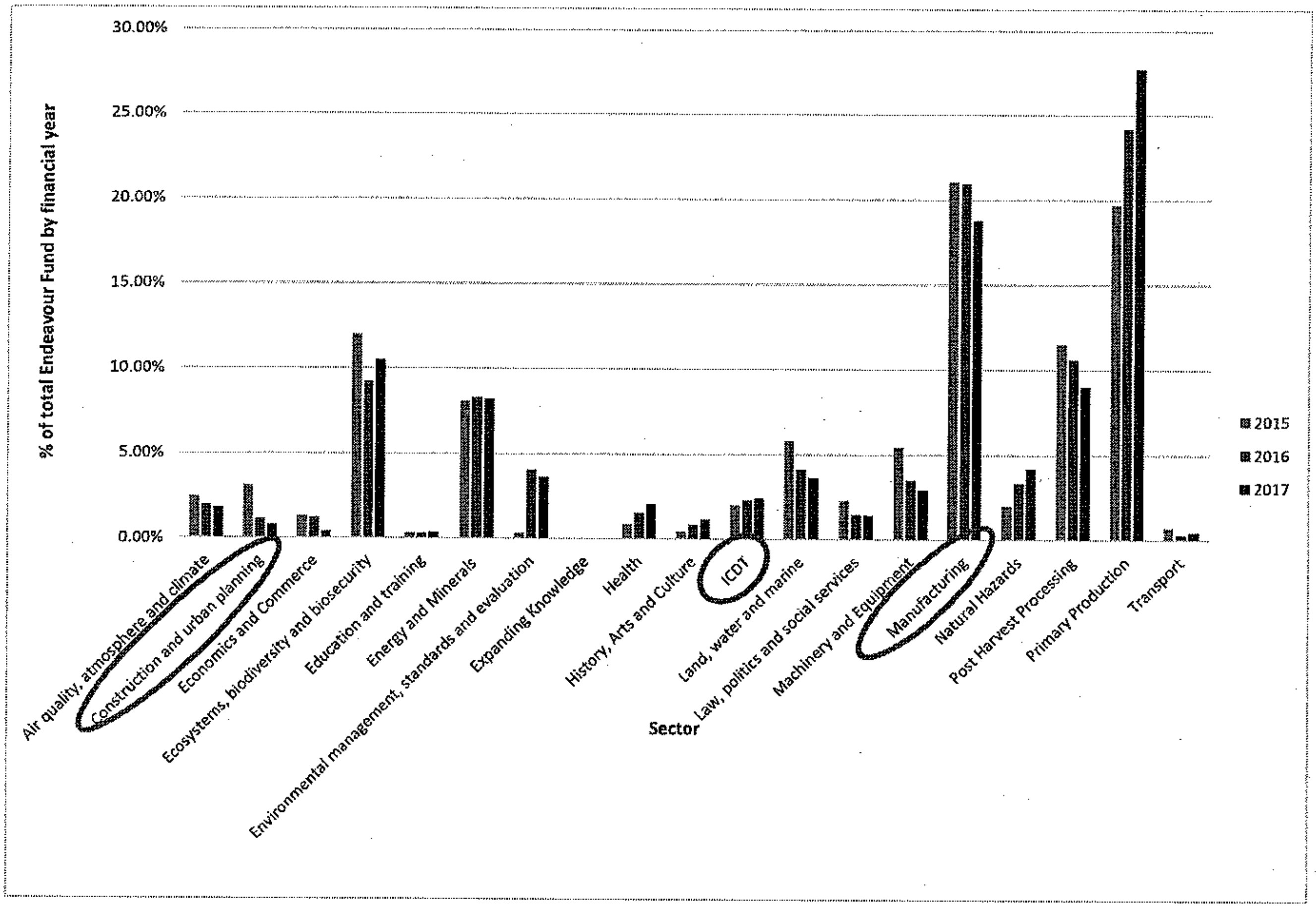




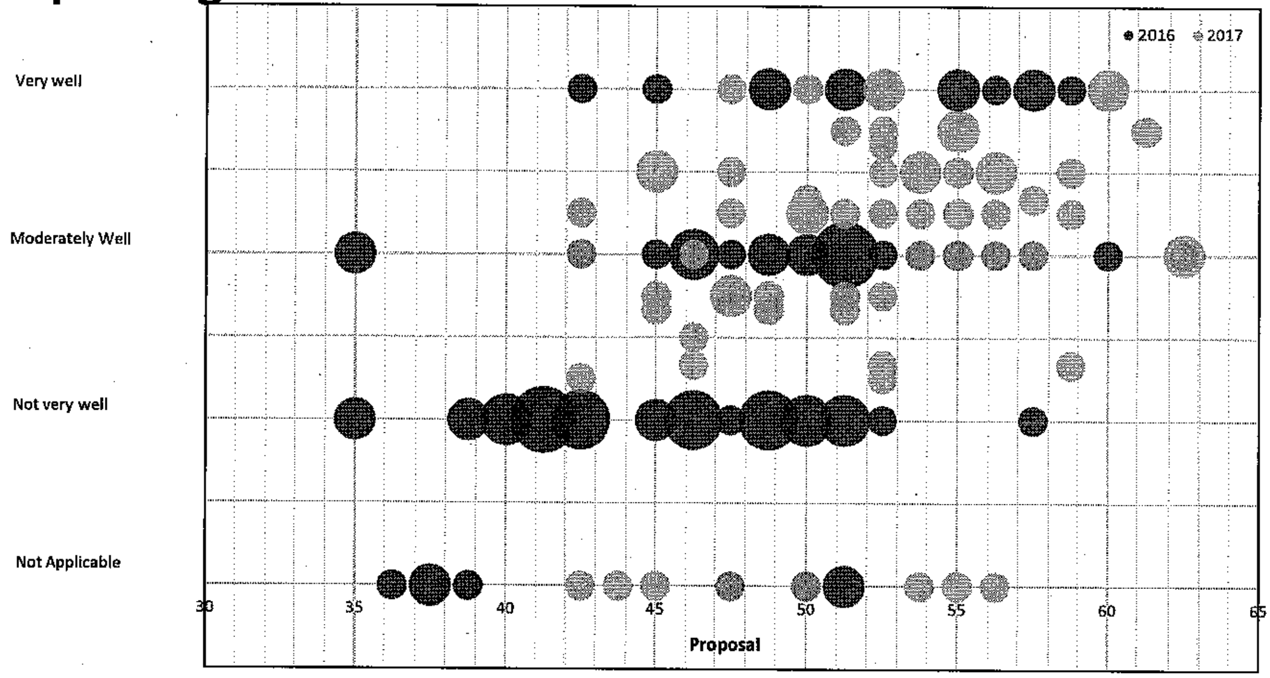


# Who Applies?

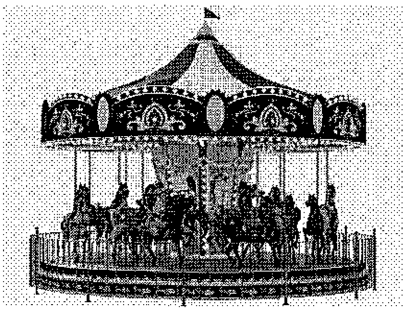




# Is applicant treatment of Vision Matauranga improving?



# Endeavour Fund 2018



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## Ngā mihi nui

## Thank you