BRIEF OVERVIEW OF ZGE TECHNOLOGY

HARVESTING DRY GEOTHERMAL HEAT

Via ZGE's Closed Supercritical System

{Overview Submitted for EARTHSOT PRIZE Nomination}

*Our **EARTHSHOT PRIZE** submittal is by the patent holder of US Patent 8,381,523 B2; filed May 29, 2009; published December 2, 2010; and issued February 26, 2013; entitled GEOTHERMAL ELECTRICITY PRODUCTION METHODS AND GEOTHERMAL ENERGY COLLECTION SYSTEMS.*

We must dispel the notion that geothermal energy is only practical within limited areas associated with seismic zones and continental rifts. Though these areas have historically been favorable, they do not constitute a limit. The idea that geothermal reservoirs must be present is also no longer the case. **ZGE's closed system technology harvests thermal energy from hot dry rock (HDR) without need of below ground reservoirs or geologic permeability.** There are extensive ***tectonically inactive*** areas around the world where remarkably high below ground temperatures, i.e., supercritical temperatures above 374°C can be reached in HDR at depths as shallow as 5 to 6 kilometers.

Supercritical Energy potential exists in some surprising places, even in ZGE's home-state of Arizona. A 1978 report entitled *Potential Geothermal Energy in Arizona* by W.R. Hahman, Sr., D.H. White, and David Wolf (W.R., D.H., and Wolf, D 1978) states the *Curie Point* across much of central Arizona can be found at depths of 5km - 10km at a temperature of 575°C. The *Curie Point*, named after Pierre Curie, is the temperature above which magnetic materials lose their permanent magnetic properties, though these properties can usually be replaced by induced magnetism. Test drilling suggests temperatures above 500°C can be reached at depths as shallow as 5km to 6km across much of central Arizona.

This historic research provides the foundation for a supercritical geothermal quantum leap into our energy future. Researchers around the world are now recognizing and acknowledging the significant role supercritical conditions can play in meeting our world's growing hunger for electricity. Power plant equipment capable of handling supercritical boiler temperatures have been in use since American Electric Power (AEP) built their Philo Unit 6 Plant, operating in Ohio from 1957 through 1975 (POWER 2013). Today AEP operates the world's first **ultrasupercritical** (593°C) coal fired power station in Arkansas, operating since December 2012 - point being, supercritical temperatures are manageable using today's metallurgy in both the fossil and nuclear fuel power industries. Certainly, we should be making use of supercritical geothermal energy as well, given it has ten times the output of conventional geothermal technology.

Simply put, supercritical energy is the future of alternative steam driven electricity generation.

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Z energy group
supercritical energy design & innovation

It is increasingly evident our global environmental and climatic goals cannot be adequately addressed by minor product improvements. Reliable, sustainable, financially feasible energy solutions require technology sector quantum leaps. Solar and wind powered electricity provided a record 10% of global power demand in the first half of 2020. Though impressive and hopeful, this is not enough. We must continue striving for solar and wind energy gains; BUT must also diligently search beyond these decades' old technological boundaries.

Solar technology for example, limited to minor product improvements for decades is not getting the job done. Charles Fritts of New York is credited with constructing the first photovoltaic solar cell, said to be 1% to 2% efficient in 1883. Bell Labs built their first 6% efficient photovoltaic solar panel in 1954 giving birth to solar power in the United States. Today, nearly seventy years later, we are reaching 15% - 22% efficiency, with better performing panels running at about 20% - an average efficiency gain of 0.21% annually. We must do better.

The UN's *Intergovernmental Panel on Climate Change* (IPCC) estimates limiting global temperature rise to 1.5°C realistically requires reducing coal fired power by 13% annually through 2030. This is problematic as China for example, burning more than half the world's coal, contributing more than 30% of annual greenhouse gases, by itself renders this IPCC goal unattainable. We can do better. Doing better demands expanding our thinking. As Professor Einstein is credited, *"We cannot solve our problems with the same thinking we used when we created them"*. In the same vein, we cannot achieve quantum leaps in clean sustainable energy progress by limiting where and how we search for solutions.

Frankfurt School's FS-UNEP *Collaborating Centre For Climate and Sustainable Energy Finance* suggest in their report titled *Global Trends in Renewable Energy Investment 2020*, that a global expenditure of $100 billion annually for the next ten years will fall far short of the Paris Accord goal of 2°C maximum global temperature increase.(Krämer 2020) Despite this pessimistic outlook, creative research in other renewables is tepid. Technological cost comparisons suggest expanding areas of research beyond wind and solar. For example, though the all-in cost of wind and solar is steadily dropping, the above mentioned GTR Report indicates on pages 28 & 29, the 2019 benchmark levelized cost of energy (LCOE) for onshore wind power averages $0.047/kWh; offshore wind power averages $0.078/kWh; and photovoltaic solar power averages $0.051/kWh. Our estimate for a closed-system supercritical geothermal system is $0.008/kWh. Closed system geothermal energy is renewable as long as earth's core remains hot, yet globally, geothermal energy is seldom mentioned as a worthwhile renewable energy source. Conventional geothermal issues aside, earth's heat is a viable energy source worth consideration, particularly dry heat at supercritical temperatures using a closed system.

Earth's civilized environment has trapped itself in an energy quandary Catch-22. Our 21st century's economic engine is driven by fossil fuel. Turning off our fossil fuel engine without a replacement energy source shuts down global economics. **The global economy must remain healthy and vibrant to finance development of earth's energy alternatives.**

No investment capital, no environmental progress. Current annual levels of energy related technological progress are inadequate to meet IPCC clean energy goals relative to renewability, sustainability, and affordability. This suggests we must leap into the future. We are currently crawling, so must learn to walk, then run into our clean energy future. Let's outline one path to that future, i.e., closed system, supercritical geothermal energy mined from hot dry rock (HDR).

ZGE's U.S. Patent for a *"closed"* geothermal system is particularly well suited for supercritical temperatures and pressures, offering a quantum leap forward in geothermal technology. Relative to conventional geothermal steam turbines, supercritical temperatures and pressures can yield ten times the electricity production at the generator. This elemental energy efficiency fact is recognized by the geothermal, fossil fuel and nuclear power industries and is being studied by scientists around the world.

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Recognizing the value of supercritical conditions relative to clean electricity generation, our Z Group Energy focus is **manufacture of supercritical water for sustainable, cost-effective, clean electricity generation**. Research, now ongoing since 2001 by the *Generation IV International Forum,* a group comprised of more than a dozen countries, is studying *Supercritical Water Reactors* (SCWR's) as a promising technology among a group of several new nuclear technologies increasing nuclear power plant efficiency. More to our point, geothermally speaking, Iceland, Italy and Japan are all working toward evolving conventional geothermal energy to more efficient, supercritical levels; the belief being, our clean energy future is supercritical.

Attempts within the geothermal industry to successfully mine thermal energy at supercritical temperatures and pressures have been hindered by the difficulty of controlling and maintaining stable pressures while harvesting heat from geothermal brines within underground reservoirs. Productively utilizing below ground fluids under high enthalpy conditions, particularly when permeability is low has additionally impeded conventional geothermal technologies from making use of supercritical conditions (Reinsch et al. 2017). Our closed system technology both simplifies and resolves these impediments, opening a new realm of clean energy efficiency within the geothermal industry.

Beyond the geothermal realm, our technology, in comparison to *Gen IV* nuclear research with SCWR's innovatively makes use of this supercritical water reactor concept by **replacing the nuclear reactor core with dry heat mined from within the earth**, thereby eliminating nuclear fuel as the heat source. Our technology is geothermal in the sense of mining heat from the earth, but similarity ends there. Our manufacturing process IS NOT geothermal in the conventional sense of extracting heat from liquid underground brines. **We are a clean, thermally dry, cost-effective, supercritical manufacturing process, not a corrosive geothermal process.**

With respect to greenhouse gas emissions, nuclear fueled energy is wonderful, has many proponents and has its place. Unfortunately, nuclear energy brings with it, serious safety, and waste issues – all eliminated where applicable by replacing nuclear reactors with supercritically heated geothermal energy via a closed, pressure-controlled system.

One wonderful aspect of our closed system geothermal technology is the ability to replace or augment nuclear reactors and fossil fuel boiler systems with our technology. This retrofitting and/or augmenting of existing power plant fuel sources, can where appropriate, salvage much of the investment in aging power plants, thereby saving billions of already invested dollars. Even if these plants do not currently have turbines or other equipment up to the supercritical task, enormous savings in fuel and waste expense can be eliminated using our system under conventional conditions, then over time, phasing into supercritical output.

In countries such as France ("Energy Transition" 2015) where many of its 57 active nuclear power plants (as of this writing) are reaching the end of useful life, replacement of nuclear reactors with a supercritical geothermal fuel source, would where applicable, save billions of Euros while providing dependable, zero emissions electricity generation.

Where an existing power plant's nuclear reactor or fossil fuel boiler system operating at subcritical conditions is replaced by our closed geothermal system, there are cases where a phased transition to supercritical conditions can cost-effectively be realized. These cases are especially attractive as connections to existing electrical grid infrastructure are in place. Reduction of expenses incurred by mining, transporting, storing, and securing nuclear and fossil fuels along with total elimination of associated fuel waste processing are considerable.

Our research suggests a competitively cost-effective retrofit to our closed system geothermal fuel source for both nuclear and fossil fueled power plants is certain at drilling depths of 6,000 meters or less; are virtually certain at drilling depths up to 8,000 meters; and in some cases, are likely cost effective at 10,000 to 12,000 meters drilling depth.

Geothermal testing carried on in Iceland ("Iddp | Iceland Deep Drilling Project" 2020) over the past decade has elicited useful flow data pertinent to our closed system geothermal technology, i.e., the subject of this submittal. Significant advances in geothermal energy have been made by the international consortium named *Deep Vision* working together in Iceland since formed in 2000. For example, Iceland's IDDP-1 geothermal well, originally planned to be 4 km deep, while being drilled in 2009, encountered a magma intrusion with temperatures of 900 °C and greater. This intrusion closed the bore hole at 2,104 m. The IDDP-1 well was salvaged with sacrificial (permanent) casing installed to a production depth of 2,069 m. Water was put down the effectively closed bore hole and the well stabilized over time. Subsequent testing demonstrated wellhead temperatures of 450°C at 140 bars with enthalpy of 3,150 kJ/kg.

Deep Vision consortium measured IDDP-1 well output as high as 36 MW_e (Fridleifsson and Elders 2005). The consortium further determined that implementing more adequate pressure controls, then reaching and maintaining wellhead temperatures above 450°C with flowrates of 0.67 cubic meters/second (24 CFS) is sufficient to produce high temperature steam generating as much as 40-50 MW_e.("Deep Vision: Big Energy from Way, Way Down" 2007).

Empirical data published by Iceland's *Deep Drilling Project* ("SAGA Reports | Iddp" n.d.) in *SAGA Report #8* (Sept. 2009), *SAGA Report #9* (Sept. 2012) and SAGA Report #10 (June 2016) as well as papers published in the *Geothermics* journal are apropos for ZGE's closed system, heat exchange conveyance to our unique Exchange Chamber for mixing and storage. Though ZGE focuses on supercritical water, as a practical matter, the average production model discussed on our website (http://zgroupenergy.com/) is based on the IDDP-1 measured sub-critical value of 36 MW_e at minimum wellhead temperatures of 450°C as published by *Deep Vision*. The closed ZGE system provides precise pressure controls for the entire heat harvesting system, so can assume pressures maintained at or above 221 bars, well above the measured subcritical IDDP-1 well pressure of 140 bars. Our closed system circumstance can provide higher net electrical output, but in the interest of conservatively estimating average geothermal potential, the lower 36 MW_e value published under less than supercritical conditions comprises the basis for our published cost estimate of $0.008/kWh.

It should be noted, *Deep Vision* computer modeling suggests a supercritical well can produce ten times or more power output than a conventional geothermal well. IDDP-1 flow testing confirms this estimate. ZGE's closed system technology means conventional geothermal expenses as well as enhanced geothermal system (EGS) expenses incurred while working directly with corrosive, sometimes toxic geothermal brines are eliminated. Hot rock wells drilled to temperatures of 450°C to 600°C can now effectively harness hot dry heat without any need for handling corrosive geothermal brines. Injection wells and injection fluid are not needed. We believe our technology can be helpful to most if not all geothermal projects.

Z Group Energy's closed well technology, with non-partioned, convective flow, coupled with ZGE's innovative Mixing Chamber(s), Exchange Chamber(s), and Pressurized Container(s) enable multiple heat cylinders (geothermal heat sources) to simultaneously work together, effectively harnessing earth's heat on a commercially viable scale. The combined discharge of multiple heat exchange wells is dynamically mixed and homogenized within one or more of ZGE's innovative Exchange Chambers. Temperature and pressure controls are both conveniently simplified and reliably enabled by this innovative system, while at the same time, safety and security precautions are facilitated.

The closed ZGE system reduces conventional operating and maintenance costs for geothermal power plants in several important respects. Injection wells, immense volumes of injection water and injection pumping expenses are eliminated along with associated injection piping and appurtenances. Treatment of corrosive geothermal brines is eliminated. Maintenance and useful-life replacement expenses of corrosion damaged wells are reduced. Potential geologic instability and fears of earthquake stimulation via long-term hydro-fracking are eliminated. The cost of fracking is therefore eliminated.

Hot dry rock necessary to ZGE's closed system technology is much more common than hot rock found in combination with underground reservoirs and high permeability as is required for conventional geothermal systems. This renders our closed system technology more technologically and financially feasible than conventional systems as well as more practical. The reduced need for expensive exploration wells searching for permeable strata and underground reservoirs further reduces financial risk. Geothermal reservoirs are rare, whereas hot dry rock is accessible at reasonable drilling depths in many areas across the world. Such advantages are significant in developing areas such as the *Syrian-African Rift* and elsewhere.

As mentioned earlier, Z Group Energy's closed well technology employing non-partioned, convective flow, coupled with ZGE's innovative Mixing Chambers, Exchange Chambers, and Pressurized Containers enable multiple heat cylinders (geothermal heat sources) to simultaneously work together, effectively harnessing earth's heat on a viable commercial scale. The combined discharge of multiple wells is dynamically homogenized within one or more of ZGE's innovative Exchange Chambers. Redundancy in temperature and pressure controls are conveniently enabled by this system, while at the same time, safety and security precautions are facilitated. These system dynamics result in important geothermal cost efficiencies.

What might a typical Z Group Energy geothermal power plant cost? A ZGE system comprised of fifteen (15) heat exchange cylinders feeding an Exchange Chamber or Chambers will net approximately 540 MW_e at the generator based on the subcritical *Deep Vision* output of 36MW_e per well. Such a geothermal power plant with projected useful life of forty or more years can be constructed today for an estimated cost of £520 million ($700 million).

The only closed system ZGE SCGHH environmental discharge is clean water, especially interesting as the ZGE system significantly reduces quantities of water needed to generate electricity compared with other generating technologies in the first place. No other energy technology compares to this cost-effective level of pollution-free electric power generation. Innovations and advancements within the energy industry typically cost more than previous iterations. Not so with ZGE's SCGHH. Feasibility is now proven by real time testing of geothermal well IDDP-1 by Iceland's *Deep Drilling Project*.

The ZGE system is sustainably renewable as long as earth's core remains hot.

Summary of improvements using closed-system subcritical or supercritical geothermal technology:

a) Hot dry rock is common to all tectonically active areas at relatively shallow depths and is more easily located and mined for heat than hot wet rock fluids thereby reducing exploration and drilling cost.
b) Hot dry rock is also common at relatively shallow depths in many non-tectonically active areas around the world significantly reducing exploration and grid connection costs.
c) Our closed system with non-partioned Heat Cylinder discharge, Exchange Chamber(s), and Pressurized Storage Container(s) provide reliable controls for adjusting and stabilizing sub-critical or supercritical system temperatures and pressures.
d) Our closed system technology eliminates conventional and enhanced geothermal reservoir issues since below-ground reservoir fluids are not harvested. We mine heat, not geothermal brines, so our closed system is not dependent on geologic permeability or replenishable reservoir levels.
e) Because our closed system does not harvest geothermal brines, injection wells and the need for enormous quantities of injection fluid are eliminated. Overall water demands for our technology are significantly less than experienced by conventional or enhanced geothermal systems. The need for hydro-fracking is eliminated along with fears of potentially destabilizing surrounding geologic strata.

f) Since our closed system uses only clean water internally, never harvesting geothermal brines, corrosion and toxicity issues are significantly reduced and/or eliminated, extending the useful life of wells while reducing operational maintenance expenses.

g) Our closed system does not depend on below ground reservoirs. Concerns regarding dry wells, receding reservoir levels, excessive water demand, permeability, and fracking are eliminated, reducing exploration expense, financial risk, and operational difficulty.

h) Our closed system uses its own internal clean water supply to convey thermal energy, avoiding exposure to underground chemicals, though we do in the case of supercritical system conditions encourage using special alloys (Guo et al. 2019) capable of handling high pressure and temperatures as high as 650°C.

i) Because our system relies on its own internal supply of clean water, pollution issues sometimes associated with underground geothermal brines are eliminated. Our system generates zero pollution emissions.

j) Drilling technology has advanced significantly, making it possible to reach temperatures above 600°C, well above the 374°C required for supercritical conditions. Iceland's IDDP-2 has already reached 500°C (iddpvideos 2017).

k) Computer modeling in Iceland and other geothermal locals predict supercritical water (>374°C at 221 bars) will produce ten (10) times the electrical energy of a conventional geothermal power plant.

l) ZGE estimates predicated on research performed in Iceland, Japan and Italy show electricity produced by supercritical means is competitive with all energy sectors.

MIT's well known November 2006 report for *Idaho National Laboratory* titled, *The Future of Geothermal Energy, Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century* (MIT, INL 2006) suggests a productive future for Enhanced Geothermal Systems (EGS). Imagine conclusions that could have been reached by this extensive, if not exhaustive 347-page 2006 report, had it been able, in 2006, to foresee today's supercritical learning curve? The report envisions a major role for EGS meeting base electric load demands in many areas. What role would have been projected with magnitudes higher output of closed system, supercritical geothermal technology? Closed system, supercritical geothermal electricity generation is a quantum leap forward in cost-effective, clean, renewable, dependable electricity generation – all with zero environmental emissions.

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Additional Background:

Generally, earth's subsurface temperature increases linearly with depth, though temperature gradients tend to increase significantly near tectonically active transition areas of continental collision and subduction. This accounts for high geothermal gradients often found beneath regions of mountain building, geologic uplift zones where thickening of relatively low-density continental rock causes earth's crust to rise isostatically, producing mountains. Such processes increase geothermal temperature gradients locally.("Landscape Evolution in the United States - 1st Edition" 2013, chap. 20)

Typical continental crust geothermal gradients within the upper 3 to 5 kilometers of earth's surface are about 25 - 30°C/km with a moderate conductive heat flux of about 0.0556 W/m^2.(Toth and Bobok 2016, 9) Such moderate gradients are sufficient for low temperature heat pump applications but not for commercial heat mining and commercial electricity generation.

Geothermal heat harvesting economics on a commercially viable scale suggest: *"Recoverable hydrothermal systems become suitable as soon as the terrestrial heat flux reaches 0.1 W/m^2, with a geothermal gradient of at least 40 – 50°C/km."*(Toth and Bobok 2016, 9, 10) It should be noted, ZGE's closed hydrothermal clean-water system is not dependent on geologic permeability, porosity or liquid reservoir recharge, though liquid reservoir convective thermal energy transfer added to typically low, hot dry rock (HDR) thermal conductivity would be expected to enhance effectiveness of the closed ZGE heat harvesting system.

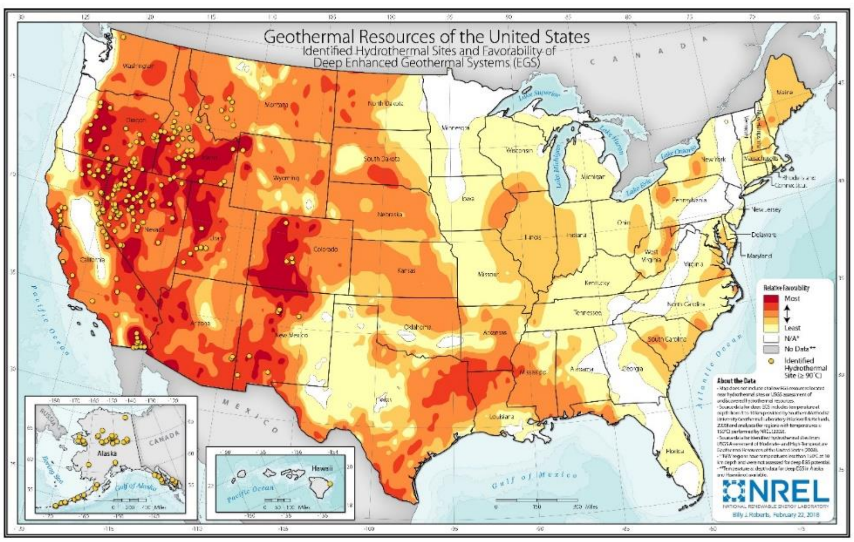
Research on the predictability of heat transference capability near the critical point of water is ongoing. Evaluation of the heat transfer coefficient (HTC) of water employing computational fluid dynamics (CFD) analysis is complicated by reliability of turbulence modeling, variable wall temperature, rapid density variation, variable buoyancy forces, and other variables (Cheng and Liu 2018). This is an exciting research area of energy dynamics potentially yielding significant improvements in effective deliverance of low-cost, low emission electricity generation. ZGE's closed geothermal system lends itself to ongoing, carefully controlled study of supercritical fluid dynamics and heat transfer related to both heat cylinder (well) and steam turbine efficiency. By eliminating the open subterranean fluid reservoir, pressure can be minutely adjusted, simplifying empirical study. As water's physical characteristics and behavior become better understood near the energy laden *critical point*, the reliability and useful life of tanks, containers, piping, turbines, and other equipment can also be improved.

As a pleasant side note, and rather interestingly, when system pressures exceed the supercritical value of 22.064 MPa (220 bars), the specific heat of water drops significantly, with the largest drop occurring from 22.5 MPa to 23.0 MPa, wherein specific heat falls from 690.6 kJ/kg°C to 284.3 kJ/kg°C. At 30 MPa the specific heat of water drops to 27.03 kJ/kg°C. In other words, it appears increasing pressure above supercritical engenders diminishing returns, effectively capping expenses near the 22 MPa limit. Sometimes less is more, though continuing work with *ultrasupercritical* temperatures as mentioned earlier may surprise us all.

It should be noted that supercritical energy investigated by **Iceland's IDDP-1** and **IDDP-2 Projects** are further supported by **Italy's Descramble Project** and **Japan's B*eyond-Brittle Project***. ZGE's closed system, non-partitioned flow and Exchange Chamber technology can cost-effectively provide significant efficiency improvements for all three of these projects.

A critical, though not often discussed economic component of supercritical energy, at least indirectly, in terms of cost is corrosion resistance of metal component parts for a sealed, supercritical system. ZGE has been following R & D regarding corrosion response of various materials within a supercritical water (SCW) environment for some time. Of recent note, we refer you to a *Science Direct* article citing *Annals of Nuclear Energy*, Volume 127, pages 351 - 363, dated May 2019 entitled *Resistance of Candidate Cladding Material for Supercritical Water Reactor,* summarizing studies conducted at *Shanghai Jiao Tong University*.(Guo et al. 2019) This work concerns corrosion test results for candidate materials such as ferritic/martensitic (F/M) steel, austenitic stainless steel, alumina-forming austenitic (AFA) stainless steel and oxide dispersion strengthened (ODS) steel. Results suggest high Cr content austenitic stainless steel, proper Cr content AFA stainless steel, and ODS steel are promising cladding materials for SCW conditions as they each demonstrate satisfactory corrosion resistance up to 650°C. *Note this research as cited, relates to water reactors specifically, but applies directly to our supercritical process as well.*

8,000m - 10,000m is an economically feasible drilling depth but, more favorable drilling depths in the range of 4km to 6km can be found in many geothermally favorable areas. In the continental United States, for example, we find such conditions in Central Arizona, Northern California, Northern Nevada, Southeastern Oregon, Southeastern Idaho, Northwestern Utah, West-Central Colorado, and Northwestern Wyoming. *Note the Yellowstone National Park area is off-limits for geothermal energy harvesting.* {Favorable equates to higher subsurface temperatures at relatively shallow drilling depths. Please refer to the NREL Map shown.} Heat productive magma intrusions where temperatures of 500°C to 1,000°C are reached at depths as shallow as ± 4,000 meters - 5,000 meters can be found around the world, often in regions where tectonic activity is inactive. This of course, reduces exploratory and operational risk.



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