Geothermal Prospection Using Existing Groundwater Geochemical and Thermal Datasets: Identifying Regions of Interest in Queensland from Government Well and Bore Data*+

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Geochemical analysis of well and bore waters has the potential to provide valuable clues in identifying regions of high geothermal potential. Chemical and isotopic markers indicative of the presence of high heat producing granites or other heat producing bodies may be mobilized by flowing groundwater and may make their way to deep wells and bores. Though likely highly diluted, these markers may also be detectable in shallow wells and bores in some regions depending on local geological and hydrological conditions. A significant quantity of data of this type already exists in publicly available government databases. These data are often coarse and of frequently unknown quality, but may prove to be a useful tool in first-order large-scale geothermal prospection. We have obtained such a dataset from the Queensland Department of Environment and Resource Management, and have extensively analysed the data with the aim of identifying potential areas of interest in geothermal prospection. This research represents the first stage of a large multi-stage project in groundwater geochemistry aimed at geothermal prospection.

Keywords: Geothermal exploration, bore water, trace element, isotope, Queensland

The Potential for Groundwater Geochemistry in Geothermal Prospecting

Geochemical analysis of groundwater may hold significant potential for identification of unrecognized regions of high geothermal potential. Geothermal source rocks, whether sedimentary, radiogenic igneous, or young igneous, produce mineralogical, chemical, and isotopic markers which can be used to identify them (Marini, L.). Many of these markers are water soluble and can thus be moved from depth toward the surface (Barbier, et. al, 1983). During the process, these markers may suffer significant dilution, but may still be detectable in groundwater samples taken at or near these thermally significant regions (Smedley, P., 1991) .

Thousands of ground water samples from across Queensland have already been taken and analysed for a limited range of water quality parameters; this data can be obtained from the State Government for research purposes. By providing chemical analysis results from almost 28,000 water wells and bores across the state, the Queensland Department of Environment and Resource Management (DERM) water borehole database is a locally unparalleled resource for conducting a large-scale first-order type investigation and identification of geothermally prospective regions within the state.

Geochemical tools

While there are dozens of mineralogical, chemical, and isotopic markers that can be used to identify potential geothermal targets, in using the data available from the DERM water borehole database, one is restricted to the limited set of parameters measured. The quality and completeness of the chemical data can be described as highly variable, with results collected and analysed by many different parties using unknown procedures over the course of several decades. Moreover, the results themselves are inconsistent between analyses, with measurements for elements such as boron and phosphorous making occasional appearances while largely remaining absent from the rest of the dataset.

While the quality of measurements may be called into question, the abundance of analyses, as well as their geographic population density in many regions, suggests that the data may still be cautiously used on a large scale (typically a few thousand square kilometres at best) to identify sources of heat at depth. From the database, initially a large number of known indicators of geothermal potential, used extensively internationally, were selected. These include the elements and compounds Na, K, Cl, F, Cu, SO_4, Zn, PO_4, and B. While it was readily acknowledged that many of these elements may be associated to non-geothermally indicative sources, the rationale for this analysis is that where a large number of notably high concentration values for these elements overlapped, these areas would be most worthy of further investigation.

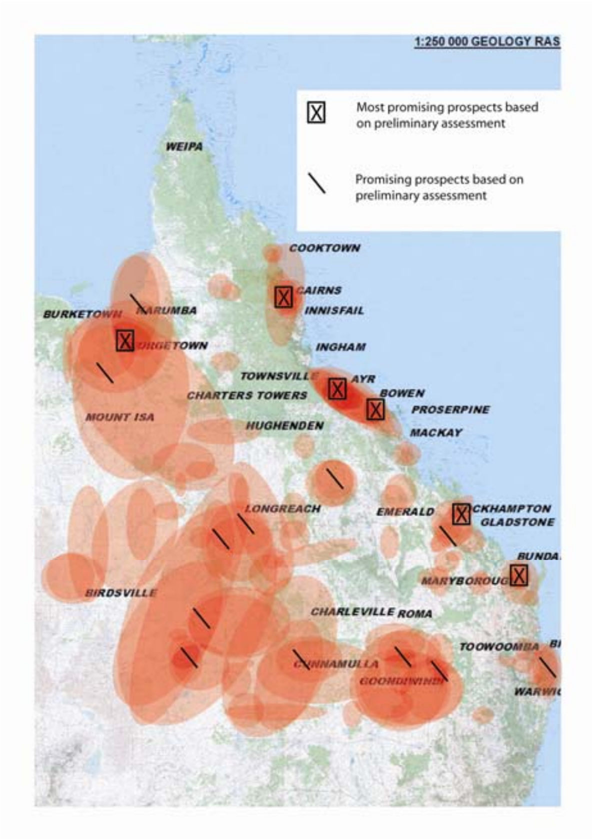

Figure 1: Early map of regions to contain potential geothermal resources based on unfiltered geochemical data. The image was composed by colouring regions with the highest potential for each selected element or compound and then overlaying all of the layers. Diagonal hashes indicate slightly promising regions while boxed X's are the most promising regions based on this early analysis.

Refining the data

With this preliminary analysis of data completed, maps of individual elements were more closely studied to assess their suitability as potential indicators of associated geothermal systems . Na and K were first discarded because of the tremendous abundance of possible alternative sources. Cl was next discarded because of its close relationship with K and Na. PO_4 was next removed as data on this element throughout the dataset was extremely sparse and because the highest values tended to be in wetter, more tropical, parts of Queensland which may simply reflect the infiltration of organic phosphate from the surface into a shallow watertable. Zn was removed both for its scarcity of data as well as for not showing any distinguishable trends or patterns when concentrations were mapped. While Cu concentration showed possibly promising results, again the data was relatively sparse. SO_4 did not show clear trends and has many possible sources, so it was initially removed. One potential source of sulphate, however, are coal measures which are known to be effective cap units to geothermal reservoirs. Thus, sulphate data may be revisited in the future to analyse the suitability of a geothermally interesting site to future exploitation.

It was finally decided to focus primarily on boron (B) and fluoride (F^-), which are both relatively soluble and abundant in felsic igneous bodies. Boron data, though somewhat sparse, shows easily distinguished trends (non-random geographical and/or geological distributions) when mapped. Fluoride data is abundant and also shows easily distinguished trends when mapped. It was additionally decided that F^- would be most indicative of buried high heat producing granites (HHPGs) at depth, as there are fewer likely alternative sources for F^- than for B.

Filtering the data

The aim of this research is two-fold. First, it is to identify potential regions of geothermal interest and secondly to identify regions on which to focus future sampling work for later stages of this research project (the details of which will be discussed elsewhere). The first filter applied was the most fundamental: many of the bores in the database were no longer existing, but were categorized as "Abandoned and Destroyed." These entries were removed as they were of no practical use to us, in that the results could not be verified by future sampling. Wells that were classified as "Existing" or "Abandoned but Useable" were left in the set. The next filter applied was for F^- concentration; after some consultation and discussion within the group, a value of 1.4 ppm was decided upon as a lower limit for water chemistries we deemed "interesting". The choice of this value significantly reduced the dataset, but left behind more than 3500 values showing easily distinguishable trends and patterns when mapped across Queensland. High values around known igneous regions, such as the Stanthorpe Granite Belt and the more recently active Cairns region, strongly suggests that this could be an extremely valuable tool in identifying igneous bodies at depth elsewhere. High values in regions not already known to contain intrusive bodies will be investigated.

The next filter applied was depth as it is likely that with greater depth comes a lower likelihood of significant dilution of circulating or simply flowing groundwater by local and relatively recent meteoric waters. Entries with bore depths of less than 10 meters were removed; however, because many entries do not have a recorded depth (and thus receive a value of zero through intermediate processing steps), values of zero were left so that wells of unrecorded depth, of which there are many, would remain. Next, because at or near HHPGs we expect to find elevated B concentrations in groundwaters, the sites with the lowest B values were removed from the remaining dataset. A cut-off of 0.3 ppm B was chosen to remove the sites least likely to show evidence of a nearby HHPG; similar to the filter for depth, values of zero were left as most of the sites sampled for F^- content unfortunately do not show B results.

Finally, with purely the aim of sample access in mind the category of “owner” needed to be filtered. Location and ownership information is provided with the data; however access to the monitoring bores is restricted to DERM staff. With these data filtered out, most of the prospective sampling sites along coastal Queensland are removed; the majority of the inland bores, which are usually privately owned, remain, allowing us to extensively investigate most of the geochemically interesting regions within the state. Coastal regions, with close proximity to population centres, however, are thereby restricted.

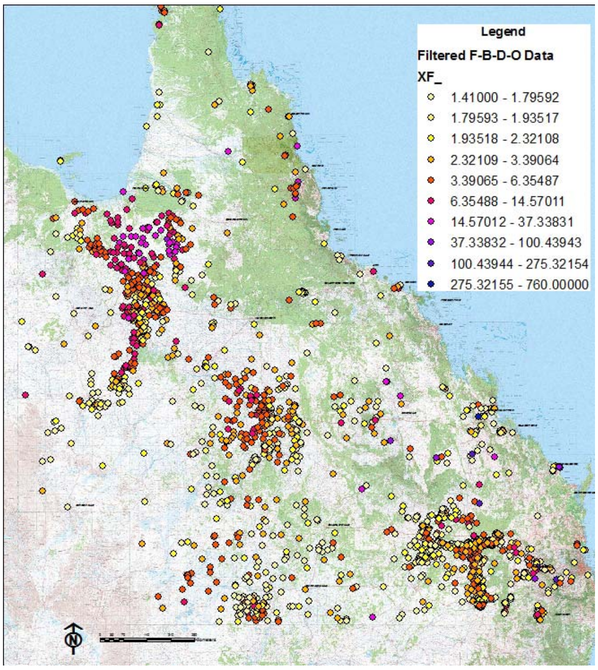

Figure 2: Water well and bore data across Queensland filtered for Fluorine and Boron content, depth, and “owner”. The colour scale is for Fluorine content in ppm.

Hydrothermal Data and Results from Other Datasets

As well as geochemical analyses of water bores throughout the state, the DERM dataset also contains water temperature data from many of these same bores. These data, however, are of limited value due to the limitations of bore depth; water temperatures are low throughout coastal Queensland and rise rather predictably with distance inland, likely reflecting the increasing depth to the water table rather than a significant geothermal gradient. These data, however, may prove useful when considered together with geochemical data in the future.

In addition to water bore and well data from DERM, there are also publically available data from exploratory coal, oil, and gas drilling in the Queensland Petroleum Exploration Database (QPED) from the Queensland Department of Mines and Energy (DME). These data include temperature results as well as geochemical analyses; because of their extremely limited geographic distribution, however, this dataset is unsuitable to state-wide geothermal prospection. A high concentration of data points in the Great Artesian Basin in Queensland’s Southwest corner may prove useful to individuals or groups investigating this known region of high geothermal potential. In a far more local context, QPED well completion reports may prove valuable as an early investigatory step in areas where such drilling has been conducted.

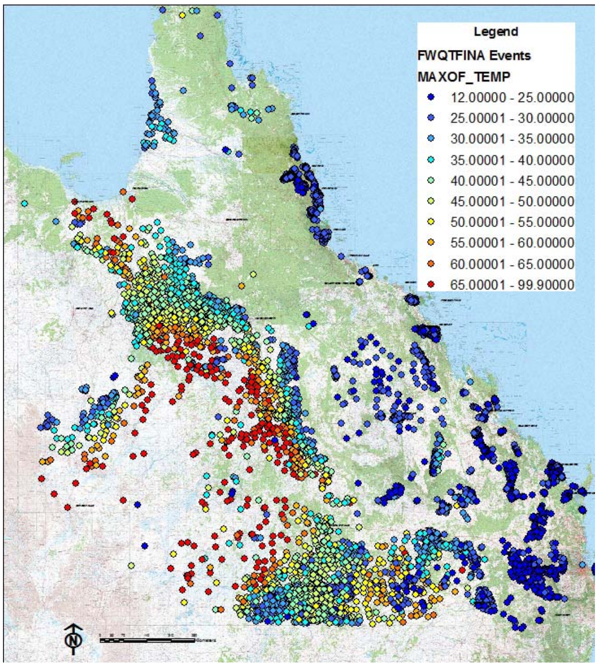

Figure 3: Unfiltered water well and bore thermal data across Queensland. The map shows maximum temperatures recorded at each site; the colour scale is for water temperature in degrees Celsius.

Summary

An extensive dataset comprising thermal and geochemical analyses of public and privately owned water wells and bores from across the state of Queensland is publicly available from the Queensland Department of Environment and Resource Management. While the thermal data have limited potential in geothermal prospection due to the depth-dependent nature of the measurements, the geochemical dataset may be of tremendous value. Chemical markers indicative of HHPGs or other heat producing bodies may be mobilized by flowing groundwater, making their way to deep wells and bores. Though likely diluted, these markers may also be detectable in shallow wells and bores depending on local geological and hydrological conditions.

We have analysed the available dataset, choosing to focus primarily on fluoride and boron concentrations, as a first-order exploratory tool to identify regions potentially containing geothermal resources and to identify sites and regions for future sampling and geochemical analysis towards that end. Several filters were put in place, reducing the extensive dataset to a more manageable and consistent and size and nature.

The Queensland Petroleum and Exploration Database publically available from the Department of Mines and Energy is not suitable for state-wide geothermal prospection due to the geographic distribution of sampling sites, but may be of significant local value in Southwest Queensland.

References

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