RESUMED **[11.01 am]**

COMMISSIONER: We will reconvene and I welcome Prof Heinson to the Royal Commission. Mr Jacobi.

MR JACOBI: Prof Graham Heinson is a professor of geophysics at the University of Adelaide. He has over 20 years' experience using magnetotellurics. His group has run the National AuScope MT Facility for the last five years and he is involved in a large range of research activities, including the national MT mapping program, AusLAMP and 4D monitoring of fluids for hydrocarbon and geothermal energy development. His group were finalists for the Eureka awards in the category Land and Water and were recent winners, in 2013, of the Australian Innovation Challenge in the category Minerals and Energy. We call Prof Graham Heinson to the commission.

COMMISSIONER: Thanks, Graham. We heard from Prof Giles about this technique, magnetotellurics, and how it might help us think about finding uranium deposits. I wonder if you could just give us a brief precis of it.

PROF HEINSON: Certainly. So magnetotellurics is an electromagnetic geophysics technique and it's sensitive to the earth's electrical resistivity which is really its ability to conduct electricity, which may sound quite esoteric but in turn that resistivity depends on things such as the amount of fluid present in the rock, some of the mineralogy of the rock, some of the big structural boundaries within the rock and the basins that encompass the top crust. So it is a technique that has been around for about 50 years but has developed quite significantly in the last 10 years and we've been doing, obviously, a lot in Australia.

It's a system which measures electrical and magnetic fields at the surface of the earth. So we use instruments that we place out on the ground and we let them record for a certain amount of time. They provide an image of the earth in terms of its electrical resistivity and that can be anything from the top few tens of metres down to the top few hundred kilometres. So we're sensitive to everything from the very near surface rocks down to the very deep part of what we call the lithosphere. That's basically the plate of the Australian continent.

The cover technique is good because it's very cheap. It doesn't rely on a big transmitter of energy into the ground. Our source of signal is from lightning strikes around the world and from solar winds coming out of the sun and interacting with the earth's magnetic field. So our signal is always present. It's always sort of humming away. So our instruments are basically just listening to the earth's response. So we can place them out in lots of locations and from each of those instruments we can learn something of the substructure.

In particular, as I mentioned, we're most sensitive to water. So in terms of a lot of what we image is the near surface sediments, what we call the overburden or the cover sequence, the regolith cover, and that contains a lot of water and pore fluids and they're quite salty which conducts electricity well. So we have very great sensitivity to the amount of cover over the basin of rocks. That's one of the great challenges for most of the geologists, is to understand what's underneath the web of material at the surface to understand what he actual crystalline rocks are at maybe hundreds of meters and sometimes thousands of metres down.

So we have sensitivity to that top layer. We also have sensitivity to the sort of crystalline rocks. In terms of what we detect, we detect quite subtle changes in mineralogy. So we're not very specific in terms of saying we can detect gold or copper oxides and so on, but generally we detect broader scale effects such as – where we have mineralisation we often have zones of alteration. That is zones where the rocks have been changed by the very hot fluids that have put the minerals there. Those give a much broader change in electrical resistivity. So we don't have tremendously great resolution as such. We can't pick up very specific areas but we do tell is something about the broad-scale kind of fabric of the crust, how it changes from one place to another, what are the processes that have led it to be as it is today.

We see a snapshot of the geometry and, I guess, some aspects of the chemistry of the earth deeper down. What we're seeing is today's imprint of what may have been a very long geological history to produce that. So in terms of actually detecting any sort of uranium or radioactive sequences, we don't have any sensitivity specifically to that kind of detail. What we do have is some sensitivity to the broader kind of tectonics or the structure of the crust that may host or may have some genesis of that particular mineral system. So we have some knowledge but we don't have a direct sensitivity to it.

COMMISSIONER: You mentioned the technology has advanced in the last 10 years. Are there changes in technology that will improve the ability of the system to find those reserves in the future?

PROF HEINSON: Not specifically in the sense that, being an electromagnetic technique, the signal diffuses into the earth. So the same way if you turn a heater on in a room the heat sort of spreads out through the room. When we have electromagnetic energy it spreads out through the earth and, intrinsically, the further down we are, the less resolution we have. Where we've seen great gains has been having many more instruments, because the instrumentation is cheaper to produce and data storage is cheaper, and also in our ability to be able to model and to be able to take those data and work out something of the earth.

I think where the gains will be is not so much in any one particular geophysical technique. So my technique with electromagnetics gives some information about the earth but it's the integration of those different techniques – seismic methods, magnetics, gravity, electrical methods. There's only one earth which produces all those signals and it's trying to work out how does one earth produce lots of different types of measurements on the surface. The real gains will be made by putting all of that information together, including things such as borehole information which gives very specific information at one place.

MR JACOBI: Can I just take you back a step and just get you to unpack some of the things you've – you mentioned instrumentation. Is this a remote sensing technique?

PROF HEINSON: It is essentially a remote sensing in the sense that we place our instruments over the surface, we leave them out for some time and then we come and pick them up and we sort of take the data off the instrument. We're sensitive to structures in the earth which might be thousands of metres or hundreds of kilometres down. So we're a remote sense technique in the sense we don't specifically look at that particular piece of rock as you would do if you were doing a borehole, say.

MR JACOBI: In terms of the coverage of information that we now have about the resistivity, as I understand, that you're measuring, in terms of the information we now have about the wider South Australian area how much mapping, how much data do we have?

PROF HEINSON: I guess South Australia is a very big land mass and, as such, the coverage is always going to be of a sort of a limited quality. Particularly because this is ground-based geophysics, it requires a person being at a location, collecting data, coming back to the same location. There is an expense and so on of each measurement. So unlike, say, magnetics where we can collect a lot of the data from an aircraft and we can cover hundreds and hundreds of kilometres in a day, with ground-based geophysics and gravities included in that sort of measurements and certainly seismics is that we're much more targeted to smaller areas. Sometimes that's a good thing because what you learn from a small area you can expand the knowledge to a much larger area.

The crust of the earth is actually very complex. It contains a lot of history. In much of South Australia it has got billions of years of history. All of that produces what we see today. To unravel that and to deconvolve all those processes to work out what happened and where, say, mineral systems might be, it's a very complex process. To get back to your point, yes, our coverage is limited, it's patchy.

At the moment, we're putting out this grid of sites called AusLAMP, which is a 50-kilometre space survey across the whole of the State. That will give us a broad sweep of the main crustal kind of elements within our region. There won't be the specifics in terms of locations of major faults and locations of more smaller changes in resistivity, but it will give us the broad scale and then we can follow up with more detail. I would say if we were looking at sort of how we're travelling relative to, say, magnetics, we're probable about 10% of what we know from the magnetic surveys at the moment. We're very limited in spatial rates.

MR JACOBI: What's been the reason for the particular focuses of the particular ground areas where these activities have already been conducted?

PROF HEINSON: Well, normally it's centred around mineral exploration, so many of the majors, the BHPs and our OZ Minerals, particular focus in on their mineral systems and do what we call brownfields exploration. So once you know something about, say, the location of Olympic Dam is to say where in the neighbourhood might we find something similar or an extension of the known systems. So a lot of focus is concentrated on areas where there's already known potential and it's just a sort of, I guess, a risk versus success story. You know, you're much likely to find things in an area you've already found things than a brand new area, what we greenfields areas. So there's large parts of the State which you might classify as being greenfields which has very little in the way of any kind of major data acquisition other than magnetics and, to some extent, gravity.

MR JACOBI: Has there been any data acquisition done on greenfield sites directed by information that you might've gathered by other techniques?

PROF HEINSON: I think in some ways, you know, the State government with pre-competitive data and the university sector. We're very interested in the greenfield areas because they represent to us both commercial and research frontiers. So a lot of our activities have been involved in looking at areas that have had very little activity and little survey work done, and certainly the State government puts a lot of time into trying to open up areas for exploration for both minerals and hydrocarbons and other energy sources.

I guess the mining companies, and particularly the juniors, obviously have to focus very much on their tenements and try and produce as much product, you know, prospectivity from a single location, and that's why they target a lot of surveys in a very small area. So we have areas of very detailed knowledge, particularly in areas around the Flinders Ranges, particularly on the western side around the Stuart Shelf and to the west around Roxby Downs and Woomera and so on, and for much of the State very little information, or very coarse information, shall we say.

MR JACOBI: And you talked about the LAMP program and the 50-kilometre - suggests a wide snapshot across the State. Will that offer you the sort of resolution that you might need ultimately to find mineral systems, or - - -

PROF HEINSON: It's sort of what we might say regional prospectivity. So in that sense, it's very unlikely that you would identify a single mineral system from this big survey, because we've got sites 50 kilometres apart, but in practice what we're doing is looking and saying, "This area here looks much more interesting to, say, mineral explorers, or in terms of understanding how sedimentary basins are formed than this area over here." So in a way, it's a sort of ranking system, if you like, of saying some areas look more interesting than others.

We approach it also obviously from a more academic and a geological point of view of saying, "What does this tell us about the Earth? How did Australia form and how did the bits join together?" So it gives us a broader scale just in terms of our geological knowledge rather than - the mineral explorers obviously like the information because it's information they wouldn't collect otherwise, and we're getting a lot of support from the States, not just in South Australia but in every State. So it's somewhere in between sort of being mineral and petroleum and more academic.

MR JACOBI: We spoke to Prof Giles. He expressed some of the sensing techniques in terms of searching for a proxy. I'm just interested to understand what the proxy is for minerals that one picks up with respect to magnetotellurics.

PROF HEINSON: Yes. It depends a little bit on what commodity you're looking for, of course, but a lot more will be focused in South Australia in what's called iron oxide-copper-gold systems, the Olympic Dams, because they're obviously the jewel in the crown, and they had a deep thermal system, which means that a lot of hydrothermal fluids have come up from maybe tens of kilometres down in the earth that had a very big pool of very hot rock at some point, maybe molten rock, that's driven a lot of fluid through the earth and as that fluid moves it changes some aspect of the chemistry of the earth.

So in terms of a mineral deposit, if we think of it as being just a small, like, tiny needle in a haystack at the top, but the source of that region might be tens of kilometres wide at 20 or 30 kilometres down, you can see a sort of residual footprint of where those mineral systems originated. So our work really comes into, you know, magnetotellurics. It's just look and say, "Can we see the footprint of what we might find at the surface." That finer scale detail, that comes down to the actual mineral companies and the commercial sites who actually investigate themselves, but we're interested in saying, "Well, what's the genesis of these systems?" I'm not sure I answered your point there. Can you rephrase the question again, sorry?

MR JACOBI: No. I'm interested to understand, when one is using magnetotellurics one is searching for a mineral system, what's the proxy one is involving?

PROF HEINSON: Measuring. Yes. So often the proxy is maybe not the minerals themselves like copper oxides and copper sulphides but some other mineral that could be something like graphite, for example, and as fluids move through the earth they dissolve and then they precipitate a lot of different minerals. We are more sensitive to some than others. We're sensitive to clay, for example, and a lot of the alteration products. The way the fluids interact with the rock itself turns a lot of that rock into clay-type minerals which conduct electricity.

So as such, we see a bigger zone than the minerals themselves and really, what we're doing, I guess, with a lot of those electrical techniques, and companies would do this as well, is they say, "We're looking for anomalies. We're looking for things that are unusual, and then we target those unusual things with either more detailed surveys or the drilling programs to confirm what might be unusual, and sometimes the unusualness is a non-economic mineral or something of very low value or low interest, and other times it's maybe what they're looking for.

I mentioned that different minerals have different signatures because they have different genesis. So, for example, diamonds have a completely different sort of system than iron oxide-copper-gold. They form different geological locations, so they have a different signature, and some of them may be very amenable to these type of techniques and others not so. So gold, for example, occurs in very low concentrations, you know, one or two grams per tonne, way below the sensitivity of almost any geophysical method to detect it. The best you might be able to do is detect the faults that drive the fluids, and if you understand something about the fault system you might have a better understanding of where to put your next drill hole.

MR JACOBI: You spoke about combining information from magnetotellurics with other information. Are there tools already available to be able to do that, or is that something that itself requires development?

PROF HEINSON: That is certainly something that requires development. That is one of the big frontiers in geophysics is to integrate a lot of different geophysical methods in a geological framework to produce realistic geological models. Generally speaking, a lot of geophysics is done in isolation, so we do one technique and we produce a nice figure and a nice cross-section and we're happy with that and we send it off to the journal. But the real benefits will come when we take these datasets and really put them together into a single framework. That's very little done though by them.

MR JACOBI: Is there a common platform that's agreed on to be able to do that, such as a GIS-style system, or are we - - -

PROF HEINSON: In terms of looking at the outputs, yes, GIS, sort of any of those systems where you can view data in three dimensions and you can work out the various combinations, but in terms of the mathematics to integrate different geophysical methods, it's very ad hoc. There are some commercial companies doing this a little bit. Quite often it's in the hydrocarbons area rather than minerals. Hydrocarbons might be geologically a little bit easier to understand than mineral systems. My sense is 10 years later we'll make a lot more progress on this. This is one of the areas that we're really lacking at the moment.

MR JACOBI: Do you have in mind that that might form part of the pre-competitive that would be generally available to those that are minded to explore?

PROF HEINSON: I think it’s – yes, it does. And I think it comes in to the sort of field of smart exploration that – the days of wild cap drilling, drilling is very expensive and not very successful from the minerals point of view. Petroleum it is much better because it is more – it is more advanced. I think the whole seismic industry tends to – I think the petroleum industry has probably a 10-year lead on a lot of what minerals does. But I think anyway where we see a lot of the major industry companies are involved, an interest in this area is to say well, what can we do now that is better than we have done before. What is going to make the step change? Because if we just keep going along as we are, we will get lucky occasionally but occasionally is not going to be good enough to really sort of – obviously you have got to keep companies afloat and to be successful. I guess all the states and all the countries around the world are looking for better approaches to exploration, to increase their own competitiveness.

MR JACOBI: Come back to the – I understand geophysics involves the measurement of other variables, things like gravity, conductivity and so on.

PROF HEINSON: Yes.

MR JACOBI: I am just interested in trying to understand the extent to which – and those perhaps more mature techniques for sensing whether there has been in essence an exhaustion of the value that can be derived from the use of those techniques as it stands in South Australia?

PROF HEINSON: To some extent, I think that is true. We get – say gravity for example, the more you infill your surveys and the higher the density, the better the resolution, so you improve your techniques and you improve your understanding with better quality data and more fine scale data. So we can improve all of our understandings by just having more of the data. That is continually happening through the state government and through commercial collection of data sets. There is a limit in the sense that a magnetic anomaly, you can get it finer and finer and finer and a little bit more sort of detailed but there is a limit in terms of ever being able to improve say our understanding of how deep something is, or what the cause of that structure is that produced that magnetic anomaly. It is a very difficult process to take data and actually understand in a geological context, particularly in areas where there is no geological outcrop because there is very little information to feed in to that geophysical model, to actually understand what is going on. So unless you have got a lot of bore holes or a lot of intersections, taking magnetics or gravity on its own, there is probably always a finite limit of what you might be able to realistically deduce from it and I guess the decision then is whether it is worth drilling or not, an anomaly based on biases and ideas about what it might show.

MR JACOBI: You pick up the topic of resolution and I am just interested to understand whether you think that there opportunities for better resolution of some of the geophysical information that is available?

PROF HEINSON: There is always a point – well, you can always get high-density data on the surface and that tends to improve your resolution, up to a level though. If you have got 500 metres of sediment above your mineral system, or your energy source, by going from say 1,000 metre spacings down to 500 metre spacings, you get a big improvement in your resolution. If you keep going down and down and down, because you the structures you are looking at are so far down in the Earth, you just don't get more information once you sort of sample perhaps say less than half the thickness of your cover. So 500 metres of cover probably - anything less than 200 metre spacing on the surface, probably won't tell you a lot more. In terms of resolution as a sort of geophysical technique, seismics has the best resolution. So seismic transects either two dimensional or three dimensional seismic array, speaking of the most detailed information, also obviously the most expensive of the geophysical techniques will give you the best information. Electromagnetics is sort of in the middle, it's cheaper. It's lower resolution. Magnetics and gravity have the most density of information but the lowest resolution. So it's a trade off a little bit between the cost and the resolution as well.

MR JACOBI: Just want to pick up we've addressed resistivity and other methods, in terms of measuring heat flow, this is something else that Prof Giles has referred to.

PROF HEINSON: Yes.

MR JACOBI: Just interested to understand what the method is for that and what that might be useful to show?

PROF HEINSON: Yes. Heat flow is really measuring between two points, how much the temperature difference is and how that material beneath it conducts heat. So when you think about it, for example if you put a stick in to a fire, you can hold one end of that stick because the heat does not transfer through the stick. There is a different heat flow than if it was a metal bar and we held the metal bar, we would know that it had been in the fire. So different parts of the Earth conduct heat better than other places. So we have two elements to our sort of thermal story in the sense that we need heat within the Earth and the bulk of the heat coming out of the continents comes out from the crust and that is from radioactive elements, particularly uranium and thorium and the decay products of those elements. What gives us heat flow is how rapidly that heat dissipates from those elements. So we have got the story of temperature and how hot the rock is but also how quickly that heat can be transferred from one place to another. In areas, much of South Australia, where we have got big sort of covers of sediments, that transfer of heat is quite slow and we get a different sort of thermal, I guess conductivity and a thermal flux than you do in other areas.

So the advantage of thermal measurements and geothermal measurements are that they tell us something about how much heat is coming out of the Earth and how it is transmitted and how hot the rock is at different levels. Now what you would use to measure it is nothing more complex than a couple of thermometers basically down a bore hole, or some kind of system where you measure, and typically you have to be below the top few – say perhaps tens of metres where the solar effects have a bigger influence than the rock beneath it. So heating and cooling of the surface is obviously much larger at the surface than it is down below. We also need some – learn something about the rock in between in terms of how well that conducts heat. So it’s thermal conductivity. There is very few thermal measurements and very few heat flow measurements have been made from South Australia, in fact throughout Australia. So it’s a very – this is one area where there is few data points, almost anywhere. And yet it’s actually a great potential in mapping out basically zones of the crust that have very high heat producing elements.

So in terms of mapping out the regions of high uranium and thorium based crystalline rock, heat flow is one of the primary measurements you can use, particularly in areas of deep cover. And as I am sure you are aware, we have a zone which sort of roughly goes around the Flinders Rangers in a north south sort of corridor and remarkably high heat flow, maybe twice the usual continental heat flow that we would expect from most areas and certainly for older continental blocks, significantly higher. So we are seeing much higher heat flow in those zones than we are elsewhere which suggests that in that region, and those age rocks, we have a much higher proportion of uranium and thorium in those regions.

MR JACOBI: Given, as I understand, that in order to take the measurements of heat you need to drill - - -

PROF HEINSON: Yes.

MR JACOBI: - - - what does measurement of heat add to being able to test the core itself?

PROF HEINSON: So to test the - - -

MR JACOBI: Like - - -

PROF HEINSON: Like a core of rock?

MR JACOBI: Well, I assume one takes assay and measure the core. What is the measurement of heat add to that analysis?

PROF HEINSON: Yes. So what – in a bore hole what you would do is you would have a string of thermistors or some kind of temperature devices that measure the temperature gradient. That will tell you the difference in temperature between say the bottom of the hole and at some point below the sort of the top few tens of metres. So you would have some kind of gradient of temperature over a hundred metres or a few hundred metres if you are lucky.

What we also need to know is how well does the material between those two points conduct heat. So we take out a piece of core, maybe a number of pieces of core, and we can measure thermal conductivity. That tells you, basically, how well the heat flows. You use those two bits of information to tell you the flux of heat, basically. It's the flow of heat out of the earth at any location. So you do need to have the two bits of information together, similarly with the analogy of the stick, holding one end and the other end. That thermal conductivity makes a huge difference in the way that heat is transferred through the rock or through that particular piece of material.

MR JACOBI: I think you've addressed the value of the measurements to analysing mineral systems. There's another potential value as well, as I understand. That's to geothermal energy. Can you explain how these measurements might assist one in planning where one might bore for geothermal?

PROF HEINSON: I think, as you mentioned earlier, the type of geothermal energy source that's being looked at in Australia and specifically in South Australia is what we call enhanced geothermal systems, the EGS. The idea with this is that we have sufficiently hot rocks at depth that have a blanket of cover of sediment over the top but that temperature is very high at those depths. If there was no sediment the heat would just be lost but if it's kind of covered over, sort of like a doona of sediment, of course that heat is trapped in there. So it's very hot at those depths. So we need the element of, basically, cover. We need the element of heat producing elements to produce high temperatures. The other part of the equation is permeability. It's the ability of the rock to allow fluids to flow.

Now, in terms of the fledgling Australian geothermal sector which had, I guess, a big boom about five or six years ago and then had some mixed success and it is now in a rather quiet of state but we hope it will come back, the problem was not so much in finding areas of heat. There are known zones of very high heat flow and we know how thick the sediments are and we know roughly how high the temperatures are at depths from the boreholes drilled, but the difficulty was getting permeability, that is to either get fluids to flow in the earth naturally or through enhanced fracturing by basically stimulating the rock. As such, almost nobody got enough flow to make the geothermal plant viable.

There is a small plant being run in Innamincka at the moment producing a bit of energy but many of the systems were very expensive to drill holes. They were typically three to four kilometres down, remote areas, quite a lot of infrastructure. A lot of the budgets almost disappeared in a few drill holes. It never quite got the success to bring in the investment to keep it going. It was really permeability that was the problem, not the temperature.

COMMISSIONER: Has anybody done that successfully throughout the world?

PROF HEINSON: Yes. There's sort of pockets of development. Nobody is operating big power plants at the moment from these kinds of enhanced geothermal systems. There was a lot of interest in central Europe, in Germany and in Switzerland, and at times the industry has sort of taken a step forward and two steps back. Part of the problem, say in Switzerland, was the induced seismicity. So by injecting, fracturing, you are in an environment of high stress, high temperatures and by introducing fluids or making fluids go you can release that stress as movement or a slip. In that case in Basel they caused a magnitude 4 earthquake which is not insignificant. Of course, that shut down a lot of the industry almost overnight, although there's still a lot of research going on.

I think the lessons which have been learned from the past, say, 10 years is that the concept of almost a wildcat drilling – you find a hotspot, you can fracture it by just pumping water in – was not successful. I think the belief now is rather than putting a lot of money into drill programs, you should put a lot of money into a 3D seismic survey because your 3D seismic survey will be able to tell you where the dominant fractures are already. If you can drill to those dominant fractures you don't have to do very much or anything to have good permeability. If you drill to the areas where there's very few fractures or very little known about the fractures, then of course your success rate is going to be much more limited.

I know that many of the research groups in the government agencies around the world are putting much more effort into thinking, rather than drilling and finding out that it's not successful, to take a step back and use geophysics and geology to produce better ideas and models first and then drill, because you'll reduce your risk of drilling areas that are not up to it.

MR JACOBI: Are the models that need to be developed, are they going to be specific to the particular rock body into which you're drilling?

PROF HEINSON: They will be very specific, yes, because - - -

MR JACOBI: Is that work ongoing in South Australia at the moment?

PROF HEINSON: No, not really. The very little kind of active research in geothermal, certainly in sort of opening up a new geothermal area of reinvestigating areas at the Cooper Basin or where Paralana is on the eastern Frome embayment, so very little activity in terms of data collection. There's still a certain amount of activity in terms of just understanding geothermal systems by CSIRO and some university groups but I think a lot of the research moved into shale gas and to coal seam gas, and some of that is moving other areas now again. So there's a movement of research, I guess, into the dominant energy sector at the time. So nothing really new is happening in South Australia in this field.

COMMISSIONER: Are all these hot rocks at the depth of three to five kilometres?

PROF HEINSON: It's a bit of a sweet spot in the sense that with the typical thermal conductivities of sediments above, to get temperatures of the order of 200 degrees centigrade it has to be about three kilometres of sediment over the top, roughly around about that. There are people looking at more shallow systems of sedimentary hot aquifers. So rather than necessarily looking at 200 degrees where there is an obvious pay-off by putting down fluids, getting up steam and driving turbines, if you look for heat exchange, just hotter aquifers, taking up water that is warmer than the sort of ambient water and then extracting the heat from that.

Obviously there's some interest, perhaps not in a very wide sense, in direct use geothermal. Not so much in the Adelaide plains. Certainly in the Perth Basin quite a number of buildings now are heated directly by geothermals. You don't really have to even drill down very far for that. You just tap a warmer aquifer and you keep the building warm at 20 degrees ambient all year around, just by using ambient groundwater.

MR JACOBI: Just interested in your view about the sorts of time frames that are likely to be involved in terms of developing commercial success out of the 4D modelling and then that leading into prototype trialing or commercial outcomes in Europe.

PROF HEINSON: It's a very difficult one to guess at in the sense that so much money has moved out of the commercial sector. There's very little driving it from a commercial point of view. To raise the significant revenues to, say, drill three or four-kilometre holes requires quite significant investment from government. I'm very optimistic that it's an industry that will rise again because it's base-load power. We can still calculate how much power there is in the ground. It's an industry which at the moment looks very difficult to be successful but you can look at various stages of petroleum exploration and say, similarly, what we do now, 20 years ago would have seemed to be unrealistic.

So, therefore, what we can see in terms of the way the petroleum industry has developed now, we can the geothermal sector potentially could go that way as well, directional drilling, smart drilling interactions with 3D geophysics and so on, and if all the elements come together of course it will be a very successful industry and it can produce a huge amount of power for both Australia and almost any continental interior that has the right mix of crustal elements, sedimentary thickness, could provide very large power sources to China, for example.

So traditionally, geothermal has obviously been in areas of volcanic rock, New Zealand and Iceland and so on, in obvious sources. It's the areas that are not volcanic away from the plate boundaries. And if the right science can be done and the right engineering, then it will be a great success, but it's hard to see it happen really within 10 years, so it's probably a longer time frame, but it's almost to the point where we should say, "Now is the time to do the right research and get the elements right," such that the next major phase of commercial development is successful and investment comes into that sector.

MR JACOBI: A discussion of geothermal, I think, has emerged from our discussion earlier on about heat flow, and we discussed a range of techniques that can be used. I'm just interested in your view as to whether there are other techniques that might be prospective to this return to mineralisation that might be prospective in terms of information we're yet to gather about South Australia's geophysics.

PROF HEINSON: Yes. Well, I did mention as well heat flow has a role in mineral systems as well, because much of the iron oxide-copper-gold systems, as we know, depends upon uranium and as such, mapping out uranium then, say, around Stuart Shelf will also be a proxy for the copper oxide systems as well. In terms of data density and gaps and so on, with such a large continental land mass of course any kind of geophysical data collection has to be very targeted. We just don’t have the population nor the resources to sort of cover the whole continent in a detailed way.

I think it's going to end up being a combination of broad-scale national datasets and discussion about, say, flying the entire Australian continent with airborne electromagnetics. What airborne EM does is provide a snapshot of the top two to 300 metres, so it's some information on the cover, and it obviously has spinoffs with terms of groundwater mapping, for example. Taken as broad scale and focusing on areas of interest with more detail is where we see advantages and I guess over time obviously that would increase.

MR JACOBI: You spoke about commercial permits being interested in sharing information, like universities and government have, you know I’m interested in the reverse and that is the extent to which information for both university and government work is available from the activities that are carried out for essentially a commercial purpose. I'm just interested to understand whether there are thought to be areas where that information could be tapped.

PROF HEINSON: Yes. There's this very mixed bag with commercial in-confidence data and we have different experiences with different sectors. So with junior exploration companies, you know, the five to 10 people type operations, a few million dollars in capitalisation, there is no problem at all with sharing data because everyone's success is somebody else's success. Everyone likes to buy in perhaps, you know, skill sets from the university or from State government and collectively, you know, it's a great team effort.

For the larger companies there's a more complex arrangement and the larger companies, the bigger they are, the more complex it is. So, for example, BHP Billiton we find very difficult to deal with at times just because personnel change so much, their operations change from Adelaide to Perth to Melbourne to Singapore, and it's very hard to build up a relationship as we might do with a junior who might be based on Greenhill Road. So there's a sense often with the largercompanies that they tend to be more restrictive of data. Not always. We have a very good relationship with Rio Tinto, for example. But it's probably never as optimal as we might like it to be, and from a university point of view we see great value in sharing data and certainly from State government in sort of that freedom of public domain data.

From the commercial sector of course they see commercial advantage and we probably don't quite find common ground between those two and so I think there is room for improvement, I think, in a way that industry and government and the research sector kind of interacts, and if we don't get that buy-in, particular from the majors, because they're the ones that often hold the biggest datasets and the largest amount of ground, we don't get that find then universities' research sector often perhaps goes off in a different area, and I think just in terms of developing technologies, developing techniques, improving kind of intellectual property, it improves the whole nation. I think there would be good scope to share more.

MR JACOBI: I'm interested to understand the extent to which there's potential information which companies, because they're targeting a particular resource, don't collect which might otherwise be of value to those conducting research or those interested in perhaps a different resource that's not targeted.

PROF HEINSON: Yes. I suspect there's always a lot of data gets collected. There are obligations to provide that to State government after a certain length of time, and certainly in acquisitions and other companies there's data transfer. I suspect there's always a sense that once a dataset, unless it's properly archived and properly looked after, once it's been collected or is too old it quickly loses value and a lot of data has probably been collected and never used very much, and it's very difficult to archive in the sense that everybody is eager?/even? no one wants to go back and archive old datasets, but there is information lost. So, for example, one company's prospectivity looking for minerals might be somebody else's information on groundwater for local communities, for example, and that information never gets traded.

MR JACOBI: As I understand, the university in terms of conducting the techniques we talked about at the start, has involved in engaging regional communities to explain the activities that it's undertaking. I'm just interested about you have any observations about what's been really important in terms of engaging with those communities and what has seemed to work well.

PROF HEINSON: Yes. That's a really good point. We're much better at stakeholder community engagement than we were, and I think part of that is that we're doing bigger programs, bigger projects that impact more people. So when I first started at the university we were doing very small scale projects and often it would be a case of ringing up the landholder, asking for permission to go on the land and off we'd go. Where we're doing our bigger surveys which have a bigger impact we're focusing on applied research that has implications for both industry, environment and social aspects. We're much focused on how we deal with community and that community is everything from the landholders in the regional towns and locations, to particularly Aboriginal groups and land groups and so.

So for the AusLAMP program, for example, which is a 50-kilometre space survey, we're obviously covering at the moment about two-thirds of the State up to a line roughly from Coober Pedy, and we spend a lot of the time talking with the Aboriginal groups about access and obviously gaining the right permits. When we're doing our surveys, as we are now in the Maralinga lands, we are taking elders and sometimes their children on the surveys to come and check the sites, but also just to be part of that survey. So we do our due diligence with sacred sites, but of course there are many more than on the sort of heritage lists. So you need that interaction to ensure that we are doing the right thing. We're learning the language.

It's an interesting aspect, going to talk to some of the regional boards and talking about, crustal elements being billions of years old and this one being 500 million years old and we're all talking to communities who have a completely different connection with the land. So what we look at in terms of a chunk here and that chunk joined on there, we're chalk and cheese in terms of what we're doing.

What we're trying to do is to be honest about how we're approaching, what our outcomes are, because we're working in that pre-competitive data space with the state government, really providing background geological knowledge. We're honest that we are not mineral explorers, we are not bringing in drill rigs, we are not looking for specifics, but we're also honest and we'll say that any bit of information we collect has an interest for a wide range of people, everything from groundwater models to deep mineral systems, which clearly no-one would ever drill on the basis of this big survey but could follow up a target. We're honest with that. So I think where we've found our stakeholder engagement is to be as clear as we can, as honest as we can and give as much lead-in as we can, and inclusive and realising that it takes a lot of time and it costs money as well. So when we first started doing the projects we never really costed any of this in but now of course it becomes very significant.

Just to give you another example, we recently did quite a big survey around Penola. Every farm there has the yellow triangle on the gate. They've locked the gate because of the worry of particularly Beach Energy, I guess, doing fracking in the environment. We were coming in from a point of view of developing geological models of sedimentary basins and some aspects of it. So we weren't involved, obviously, directly with industry but we were producing geological models. We would ring up lots of people, we would go to their houses, we would talk to them. The more engagement we had, generally the better everyone felt about it and we followed it up with surveys and feedback to them afterwards.

We're still getting better at this but what we've realised is where we thought initially it was sort of that much of a project, 10 per cent of a project, we now realise that probably 30 or 40 or maybe more per cent of a project is making sure we do it correctly, because the long-term benefit for us and everybody else is much more important than simply getting one set of data.

MR JACOBI: Have you had any particular success in a particular method of explaining the science or the techniques of what it is that you're doing?

PROF HEINSON: It's a good question. Sometimes we explain and we can see that people glaze over and we realise – we're trying to talk science and, of course, people don't have a science background and there is, I guess, a certain amount of belief and misbelief within the community. So I think in the sense of just communicating what we do in the best possible way and the way we can do best, even though people don't understand necessarily what magnetotellurics is, for example, they understand that we are approaching them in a consultative manner. So we don't necessarily, I'm sure, get the science message across but what we do try and get across is that we're not bulldozing in over the top of a community.

Now, we have probably done it quite easily because we're from a university. With the state government the university particularly, I think, gets a good run because we're not seen as having any commercial kind of allegiances but, still, I don't think there's any really significant difference we're doing than perhaps everybody else do or could do.

MR JACOBI: I just want to change the topic entirely, and that is just to address just in the time that we have available, perhaps very briefly, issues of tectonics which form part of geophysics. I'm just interested in your perspective, really, about the ongoing potential for tectonic movement in South Australia, if you can offer some broad perspective in relation to that.

PROF HEINSON: Yes, certainly. Australia is a very stable continent. We have no plate boundaries through the continent as such. So in that sense we've been an integral continent for 500 million years when the eastern part of Australia really docked on the western part of Australia. So much of the kind of continental interior has been stable for hundreds of millions of years, if not billions of years. Now, obviously we are surrounded by plate boundaries. So the tectonic forces at those boundaries cause stress within the plates.

We've had Antarctica break away from Australia. So we have had a boundary develop and then significantly move away now of course, but what we might recognise as Australia now has been stable for a long geological time scale with no major tectonic events other than we have a sort of volcanic chain that runs down the eastern side of Australia called, in Victoria, the Newer Volcanics Province. Mount Gambier, Blue Lake and Mount Schank are the most recent of those volcanoes. They're only four and a half to five thousand years old. So they're a little pinprick of heat coming up from a source of heat 100 kilometres down. So slightly an unusual sort of scenario but not something that causes a major tectonic effect as such. It's relatively small scale.

So within South Australia we do have zones of tectonic weakness in the sense that they are the told crustal blocks but the edges of those blocks are zones of a little bit more weakness than in the middle of the those rocks. So taking one step backwards again, we have the Gawler Craton, for example. It's an Archean core. It's basically an old continent which is two or more billion years old. So much of Eyre Peninsula, a little bit of Yorke Peninsula, right up to sort of Coober Pedy, that's an old chunk of continent sort of floating around on the earth's surface. Bits of it are joined around the edge and gradually accumulated as it is today.

Where we've got the edges there are zones of weakness and we have a prevalent stress field through the continent. Now, as you can imagine a continent and a plate is a tectonic element. It's a bit chunk of something. As it collides into other things, that stress moves through the plate. Currently, much of our stress that we find comes from the collision of India, which is on the same plate as Australia, with Eurasia, forming the Himalayas. That's the sort of buffer zone, it's a crumple zone and it's a sort of push-back from the continent.

So where we see that now is of course we get a number of earthquakes through the Flinders Ranges, really from Mount Lofty Ranges and through the major faults that run through the Adelaide plains and the (indistinct) along the edge of the hill scarp, all the way up to Arkaroola. It's one of the more seismic, more earthquake prevalent areas within the Australian continent. Many of these earthquakes are relatively small, magnitudes 3, occasionally a 4, many 2s and hundreds of 1s that we hardly notice. So we have a sort of zone that we can – you can see it on a map and I'm sure Geoscience Australia will show you many of these maps this afternoon.

These are not zones particularly where we would expect very large earthquakes and we don't expect to see significant tectonic events such as big slippages and any kind of major zones of melting, for example, any kind of zones that might be considered to be anomalous. So the actual continental mass of South Australia, and we can include much of Western Australia and northern

Australia and sort of the older part of Australia, is very tectonically stable. It has been for billions of years.

MR JACOBI: I'm just wondering whether that could be expressed in terms of its relativity to other places in the world in terms of their seismic activity.

PROF HEINSON: Well the most seismically active, the most earthquake prone zones are in areas of either subduction, that is where one plate slides under the other and much of Japan and Indonesia and bits of New Zealand are of that category. So the really big earthquakes, and the earthquake which just happened off of Chile where the Nazca Plate subducts underneath the Americas Plate is – they are called subduction plates, they have a very large stress and when things break, they break with a lot of energy. There are strikes where there is two plates finish side to side and San Andreas Fault is the major example of that. These are the zones where we get the magnitude eights and occasionally a nine and sevens and many more sixes. Because are the zones of the major stress, the major push between two plates. So globally we can map out, we can look at really where all the earthquakes have happened over the last week, or month or year, or 10 years, or a thousand hundred years, we can map out the zones that have the most earthquakes.

If you look to the Australian plate, we are almost a desert of earthquakes. Very few major earthquakes at all. Occasionally. There is always the potential within a continent to have a bigger earthquake just because of the kind of accumulated stress and then a cycle of events but they are very rare by comparison. So globally, the interior part of Australia is right down at the lowest point in the sort of risk factor. Now as a whole, very few earthquakes locally. There might be zones of more earthquakes. Bass Strait, the Flinders Ranges the Darling Fault along the edge of the Perth Basin. The earth – sort of the Sydney Basin and so on. Some of these are basically faults that lie on the edges of basins, that is basically where you have got sediments and you have got sort of the original basement rock, you get a sort of a difference in density and you get sort of a movement along those fault lines.
Flinders Ranges is really almost like a little bit of a weakness zone where you are pushing it together a bit and pushing up the Flinders Ranges, pushing up Mount Lofty and you are causing a few more earthquakes there. Globally, it’s relatively low concentrations but regionally and nationally they are the most prevalent areas.

MR JACOBI: Just want to finish off, just what you have just explained in terms of what is the evidentiary basis from which the particular conclusions that you have just expressed are based?

PROF HEINSON: Well, we have good global records of earthquakes probably over the last 50 years. Before 50 years, I guess the network of coverage was much lower and also just the ability of storing data and having data available. So prior to say 1950 or so, much of what we know about earthquakes is either documented in terms of the way people felt earthquakes, perhaps in newspapers and so on. But since 1950's, certainly since the advent of data, digital data, we have very good records of data on earthquake kind of occurrences. So even though they are shortish time span obviously compared to the history of the Earth, or (indistinct) history of the Earth, we can tell where there is a greater risk and a lot of risk. We can't rule out any area having zero risk.

There will always be some risk but there will – we could assign a sort of a league table if you like and say there are areas of much higher probability than others. So in terms of our sort of global catalogue, we know something from just the kind of archive of records over the last 50 years or so. If we wanted to look a little bit further, we would look for evidence of movement of the Earth's surface over the last say few hundred thousand years. And the way we might recognise that is some topographic change. We might recognise it as a displacement of sediments and we can get an idea of how often earthquakes occurred by how large say a topographic feature is maintained.

Generally, weathering of any continent will reduce topography down as fast as it can. So any evidence of sort of changes in topography where we wouldn't normally expect topographic changes, so for example over some of the Stuart Shelf there are bits that are a little bit higher than other bits, are evidence that there has been earthquakes in the past that have moved the ground up and down a bit. We call this neotectonics. Basically it is the new tectonics – it's beyond the scale we have perhaps written or data that would support this but it's not too far back in the sense that other – the whole framework of complex geological events would have made it very difficult to understand.

We are almost looking at time scales in which the continent of Australia looks very much the same as it is today but we can see evidence of minor scale change. So we can get some idea of seismic and earthquake hazards over longer time scales, hundreds of thousands of years, by looking at topography and by looking at sediments and so on. That gives us, again, a little bit more of a risk map and I am sure Geoscience Australia will talk about their risk mapping, particularly for cities but just generally about their sort of knowledge of how the Australian continent is continuing to sort of buckle and change a little bit, not much but a little bit.

COMMISSIONER: Thank you very much Prof Heinson. Thanks for your evidence. We will now adjourn until 1.30 when we will have Dr Stephen Hill from the Department of State Development. Thank you.

PROF HEINSON: Thank you very much as well.

ADJOURNED **[12.06 pm]**