Podcast #82 – Natural Hydrogen Wells

[00:25] **Brian:** Well, hello everyone, and welcome to the Hydrogen Nowcast for February 9, 2024. I'm your host, Brian DeBruine, the director of the non-profit Colorado Hydrogen Network. This is a podcast devoted to encouraging the deployment of hydrogen infrastructure throughout the world. Our intent is to encourage and motivate others to take charge to help deploy hydrogen as a means to decarbonize the transportation and other energy sectors and to accelerate the movement to stop climate change.

Well, regular listeners to the podcast may recall that I previously recorded a podcast about the natural occurrence of hydrogen titled Natural Hydrogen Wells, which was on September 16, 2022. And that podcast featured an interview with Viasheslav Zgonik, whose company is Natural Hydrogen Energy, and that website is nh2e.com is based in Colorado and Paris. But I think it's warranted to record another podcast on natural hydrogen since this field is developing rapidly and much of that progress is actually happening here in Colorado.

So on the podcast today, I'm really pleased to welcome Geoffrey Ellis, who's a geologist with the US Geological Survey and holds an affiliated faculty position in the geology department at the Colorado School of Mines. Geoff, welcome to the show!

[01:44] **Geoff:** Hi Brian. Thanks for having me.

[01:46] **Brian:** Well, so glad you're willing to spend some time with us today, Geoff. We really appreciate that. So, Geoff, Colorado seems to be a hotspot for work in natural hydrogen. In addition to Viasheslav's company that I just mentioned, nnh2e.com, the company Koloma, that's spelled Koloma, and their website is koloma.com, is also in Colorado, and they recently received over $90 million of funding from Bill Gates foundation, Breakthrough Energy. So we'll talk to all that.

But let's start with you telling us about yourself, your work, the work that's going on at the Colorado School of Mines and the US Geological Survey. And by the way, listeners, we're going to refer to that as USGS.

[02:30] **Geoff:** Sure. So I'm a research geologist with the USGS Energy resources program, and I've been doing research related to natural gas geochemistry for over 30 years. I recently started a project within the USGS looking at the resource potential of natural hydrogen. This project is trying to better understand the geological processes that could lead to the formation of economic accumulations of hydrogen in the subsurface. And then we're using that knowledge to try to map out the prospective places to look for hydrogen and also develop exploration tools and strategies to guide geologic hydrogen exploration. In addition to my work in the USGS.

I'm also leading a research consortium with my colleagues at the Colorado School of Mines and from CU Boulder. This is an industry funded research program that's supported by the companies that you mentioned, as well as other natural hydrogen startups and major companies from the oil and gas and mining sectors. This program specifically is focused on the development of exploration tools. And to my knowledge, this is the largest research program on natural hydrogen resources in all of North America. So you're absolutely correct when you say that Colorado is a hotspot for this field.

[03:41] **Brian:** Well, we're proud of that.

We're starting to learn that natural hydrogen is NOT that uncommon an occurrence. And so the first question people ask is, why did we not know about this before?

[03:55] **Geoff:** Yeah, I get asked this question a lot, and the simple answer is that we just weren't looking for it in the right places with the right tools. And I think this was at least partly due to the fact that geoscientists had assumed that natural hydrogen accumulations simply couldn't form. And that assumption came from the observation that out of the hundreds of millions of oil and gas wells that we've drilled all around the world, hydrogen is rarely found at more than trace levels. And so the rationale was put together that this was probably because the small size of the hydrogen molecule and its reactivity, both biologically and abiotically, meant that it would just simply leak out and get consumed before you could form an accumulation.

[04:37] **Brian:** So what actually happened that changed our thinking on this?

[04:42] **Geoff:** Yeah. As often happens with scientific discoveries, it was actually a lucky accident. Well, it was lucky for us, not so lucky for the people who made the discovery. Back in 1987, there was an Italian company that had been hired to drill a water well in a small village in the country of Mali in West Africa. And while they were drilling, one of the drillers was smoking a cigarette and accidentally ignited some flammable gas that was coming out of the hole. Fortunately, no one was seriously injured, and they eventually put out the fire and plugged the hole. And then they moved to another nearby location and successfully completed the water well. So that plugged hole sat there for 25 years until a petroleum company that had heard about this incident came to the village and drilled a new gas well at the site of the accident. Now, they were expecting to produce methane rich gas, but when they analyzed the gas chemistry, they were shocked to find that it was almost pure hydrogen. And in the years that followed, they conducted an extensive exploration campaign that identified multiple stacked reservoirs charged with hydrogen gas. Now, we don't know exactly how much hydrogen is there because the development of the field has been hindered by geopolitical problems in the country, but it almost certainly represents a substantial economic accumulation of natural hydrogen. And news of this discovery really began to get noticed by geoscientists around 2018 or so. And since then, there's been a small but growing number of research groups that are working to try to understand the resource potential of natural hydrogen.

[06:11] **Brian:** Okay, well, speaking of the resource potential, we know that hydrogen is a small molecule that leaks easily, and it's very reactive. But we now have this one economic accumulation of hydrogen. What does this really tell us about the potential for resources elsewhere? I mean, could this be a significant energy resource on a global scale?

[06:33] **Geoff:** Yeah, that's a great question. Unfortunately, it's one that we don't have a very precise answer for just yet. There's nothing particularly unique about the geology of the Mali site to suggest that it couldn't happen elsewhere. So it seems likely that there probably are other accumulations out there.

I've done some work with a colleague of mine at the USGS to build a model to try to get a sense of the rough magnitude of how much hydrogen might be trapped in accumulations in the earth's crust. And to do this, we started with what's known about the behavior of hydrogen in the subsurface, things like the rate of generation and the amount that could be consumed. And then we filled in the gaps with analogs from other fluids like helium and petroleum. And we put a range of values on the inputs and ran a Monte Carlo Simulation to predict how much hydrogen might be trapped in the subsurface. And the range of output values that we get is quite large, from thousands to potentially billions of megatons of hydrogen. And remember, a megaton is 1 million metric tons. And for context, the world currently produces about 100 megatons of hydrogen per year. I've seen some projections from the International Energy Agency that in order to reach net zero, the world will likely need around 500 megatons of hydrogen per year. Now, the most probable value for the amount of hydrogen in the subsurface from our model is around 5 million megatons. However, it's very important to realize that this is a model for the entire Earth's crust. So the vast majority of that hydrogen is very likely to be inaccessible. And by that, I mean that it's going to be in accumulations that are too far offshore or too deep or too small that they would never be economic to produce.

But for the sake of the argument, let's say that 2% of that 5 million megatons were in accumulations that are economic, that would be 100,000 megatons. And that could supply all of those 500 megatons per year for 200 years. So, for me, the takeaway from this exercise is that it's very likely that there are significant hydrogen resources. That could be economically recovered. And the key questions that we need to look at are related to the geologic crisis that could actually lead to accumulations.

[08:46] **Brian:** Okay, well, speaking of the geology, let's talk about that. Could you maybe give us a simple overview of what we know and maybe what we still need to learn about how natural hydrogen is formed and where it occurs? And then that, of course, leads to the question of how we prospect for it.

[09:04] **Geoff:** So, at the USGS, we've been working to develop a conceptual geologic model for understanding the potential to form natural hydrogen accumulations. And this is based on the petroleum system model, which has been very effective in guiding oil and gas exploration for decades. Both models are composed of a number of components. That are required to form an accumulation. So these are things like the source migration pathway, reservoirs, traps, and seals. And now, some of these components may be similar for both systems, but in general, most are quite distinct. So, for example, the source of petroleum is organic rich rocks. That have been heated deep underground for millions of years. For natural hydrogen, there are several different sources that are thought to be possible.

The first and most widely accepted is the reduction of water by iron rich minerals. This process occurs rapidly and can be observed in real time in nature, at mid ocean ridges and other places. There are a lot of iron rich rocks in the earth's crust. And the volume of hydrogen that could potentially be generated this way is really quite substantial.

A second process that's frequently cited is the radiolysis of water. And this is the splitting of water by the natural decay of radioactive minerals.

There's a third and more uncertain source. That is, these deep faults that bring up fluids from the mantle. And this one is more controversial because the source of hydrogen is not well constrained. It could be generated by reduction of water in the mantle, or possibly even be primordial hydrogen that's been trapped in the earth's interior since the planet first formed. In addition to the source, the migration of hydrogen is also likely to be different from hydrocarbons. Although most fluids move by advective flow, where they're driven by buoyancy forces and follow the path of least resistance. Hydrogen is generally more soluble in water than hydrocarbons, so it will likely move differently than, say, methane. It's also much more reactive. So it's more susceptible to loss along migration pathways. Other components in the hydrogen system, like reservoirs and traps, are likely to be similar to those for natural gas. I should caution, though, that these are very high-level concepts at the moment, and there's still a lot that we have to learn. That said, though, there are companies that are applying these ideas to natural hydrogen exploration already, and as they drill more wells, we should get more important information that will help refine these models.

[11:29] **Brian:** All right, well, speaking of the wells, let's talk about that. Are these just simple bores, like a water well, or is there some form of underground development needed, like fracking or something like know?

[11:42] **Geoff:** Yeah, that's good. I'm glad you brought this up, Brian. There are actually three distinct approaches for developing natural hydrogen resources that have been proposed so far. We've been talking about natural hydrogen resources in accumulations similar to natural gas. And this type of resource play can be developed with conventional oil and gas drilling technology, most likely without any sort of stimulation. One caveat being that a higher grade of steel is needed in the wellbore construction due to the potential for embrittlement caused by hydrogen. But there are other ways to produce natural hydrogen. Because the rate of hydrogen generation is so fast compared to hydrocarbon generation, it's been suggested that we may not need reservoirs and traps at all. It's possible that we could drill down into porous zones in the subsurface where hydrogen is flowing and produce it as it's being generated or possibly migrating. If it's primordial hydrogen, this would be more analogous to geothermal energy production than to natural gas.

Another idea out there is to stimulate hydrogen generation. There are many possible ways that this could be done, but one obvious way would be to drill down into some iron rich rocks and inject water to induce hydrogen generation. This most likely would require fracking and has a whole host of potential environmental and engineering challenges. But it could be a very significant source of hydrogen. This idea is so attractive that the Department of Energy's advanced Research program, ARPA-E, has recently launched a $20 million program to investigate this idea.

Now, to me, the conventional accumulations of natural hydrogen seem the most viable. There are so many known accumulations of natural gas and other gases like helium and co2 out there, and we have this one known accumulation of hydrogen in Mali. To my knowledge, we've never produced gases from a subsurface flow. And as I mentioned, I think that stimulating hydrogen generation will be challenging. So I view these approaches as quite risky. That said, going back to the model predictions, that we discussed earlier, that estimated 100,000 megatons of recoverable hydrogen that I cited. That's only for hydrogen trapped in accumulations. If we could actually produce hydrogen from these subsurface flows, or stimulate hydrogen generation, then that would considerably add to the resource potential. So I think it's certainly worth pursuing research into these ideas.

[14:07] **Brian:** Oh, yeah, absolutely. Well, you mentioned that several of the processes are ongoing, and so they're continually generating hydrogen, and I think it's for that reason I've heard it said that natural hydrogen is considered a renewable resource. So what are your thoughts on that?

[14:23] **Geoff:** Yeah, so there are some people who advocate for this notion, but it certainly isn't universally accepted amongst geoscientists who are working on natural hydrogen. Supporters of the renewable hydrogen concept often point to the Molly field, where it's been reported that the reservoir pressure has actually gone up over more than ten years of production. But you have to realize that there's only one well, and it's producing no more than about 1500, which is not very much, just enough to provide hydrogen to a generator that's making electricity for a small village. So this isn't really commercial scale production. Additionally, there's an aquifer below this shallow gas reservoir, and it's saturated with hydrogen. So most likely, as the hydrogen is withdrawn from the reservoir, it's being replaced by hydrogen coming out of solution in the aquifer and not really being generated in real time. And we looked at this question of renewability when we did our model of the potential volume that could be in accumulation. And our model suggests that the amount of renewable hydrogen in these systems is really quite small. So I think in order for natural hydrogen to be truly a renewable resource, we'd need to be able to produce it from these hypothetical subsurface flows where it's being generated in real time. At this point, we don't have any data to evaluate this potential. So I keep an open mind about these sorts of questions, and I would say that we just need to do the research to definitively answer this.

[15:49] **Brian:** Yeah, well, this is a new science, and we've certainly got a lot to learn. Now, I've heard before, and I understand, that natural hydrogen often occurs along with helium, which is another really valuable industrial gas. Now, to separate and purify those gases, I know we could use something like electrochemical compressors, which are very similar to PEM electrolyzers or fuel cells. And by the way, listeners can learn more about that from HyET hydrogen. That's HyET Hydrogen, and their website is hyethydrogen.com, and actually, I plan to have them back on the podcast again soon. But Geoff, could you talk about what actually comes out of the well and what kind of processing we're going to need to do on it?

[16:31] **Geoff:** There are a number of gases that can be found in association with natural hydrogen, depending on your perspective. Some of them are good, some are bad, and some are neutral. You mentioned helium, and clearly this is a valuable commodity, and it is often found in association with hydrogen. This is because the decay of radiogenic minerals produces helium and can also split water to make hydrogen. If the helium concentration is above about 0.3 volume %, it's economic on its own. So co-producing helium and hydrogen makes a lot of economic sense.

Another gas that's commonly found with hydrogen is nitrogen. Since our atmosphere is mostly nitrogen, this can be vented without any environmental concerns. So this one's benign.

A third gas often found with hydrogen is methane. Now, methane is more problematic. You certainly don't want to release it to the atmosphere. There are several ways it could be handled, depending on the end use for the hydrogen. It can be separated and used on site to power equipment like compressors, or it could separately be put into natural gas pipelines. However, at some point, we may start blending hydrogen into our natural gas supply to lower its carbon footprint. And if this became widespread, then coproduced hydrogen and methane wouldn't need to be separated at all.

[17:50] **Brian:** Oh, yeah, good point. Well, you mentioned that geoscientists really started to take notice of the potential for geologic hydrogen around 2018, and this was also the year that the first well explicitly targeting natural hydrogen was drilled, and that's in Nebraska, which is just east of Colorado. So it's been six years now. Why haven't we seen more rapid development of this resource if it has so much potential?

[18:14] **Geoff:** Yeah, that's a complicated question. Resource development is fundamentally dependent on economics. Someone needs to be willing to invest money into exploration and production with the expectation that they'll ultimately make a profit. But natural hydrogen is such a new concept. We don't have proven exploration tools, and we don't have a history of successfully predicting where to even look for the resource. So this makes exploration very risky. Investors expect high returns on high-risk investments, which I think is slowing development.

I think that much of the investment into natural hydrogen startups to date is driven by climate objectives, more than profit motive. Actually, you mentioned Bill Gates' *Breakthrough Energy* fund investing in Koloma. This is a good example of that.

We do have governments starting to invest in natural hydrogen research. Also, the USGS working on hydrogen systems research and mapping resource prospectivity. And as I mentioned, DoE is investing $20 million into stimulated hydrogen research. The government of Australia is now funding several research groups working on natural hydrogen. And the president of France, President Macron recently announced that France will make massive investments into natural hydrogen, although we have yet to see what that'll really look like.

But the other side of this is markets. Right now, the hydrogen market is relatively closed. There are a small number of companies that are making hydrogen for a pretty well-defined demand. So it's not like there's a lot of customers out there looking to buy hydrogen right now. I think with the development of these new hydrogen hubs that are planned, that really might start to change.

[19:44] **Brian:** Well, let's hope so. And I'll just echo your point about market. I mean, if you put in a hydrogen well and spend the money, you may not have a buyer for that hydrogen just yet. So we've got to kind of bootstrap and bring the supply and the demand up at the same time as we do in so many areas of hydrogen.

Well, Geoff, as we start to wind down the podcast, is there anything we haven't talked about that you'd like to add?

[20:08] **Geoff:** I would like to mention that late last year, there were two exploration wells drilled on the York peninsula in South Australia. These were drilled on the site of a couple of historic wells that found over 70% hydrogen about 100 years ago. The new wells found very similar concentrations of hydrogen, which suggests that there are one or more accumulations down there. This is probably not some transient flux of hydrogen.

There's also a couple of new wells plans to be drilled in Kansas in the early part of this year. The results from all these wells should be very informative. If the companies can demonstrate commercial scale flow rates of hydrogen, that will almost certainly accelerate interest in natural hydrogen.

Finally, one last thing I want to stress is that what we've been talking about today is potential natural hydrogen resources. At this point, we really don't know how much natural hydrogen is available in the subsurface. We need to collect much more data and do much more research to understand where these resources might be and how to explore for them. There's still a lot of work to be done, Brian.

[21:08] **Brian:** All right, well, Geoff, thank you for being with us today. I know you're a very busy guy. We appreciate that.

But listeners, I've been talking with Geoffrey Ellis, who's a geologist with the US Geological Survey and also on the faculty of the Colorado School of Mines. Now, the School of Mines website is simply mines.edu. Now, Geoff, I understand there's a USGS geologic hydrogen site coming?

[21:32] **Geoff:** Yes, that's right. We're in the process of standing up a site on geologic hydrogen. That's where we will be posting the results of our prospectivity mapping as well as other products that we're putting out so people can check the USGS website, USGS.gov, for that in the coming months.

[21:49] **Brian:** Okay, very good. Well, thanks, Geoff.

Well, listeners, if you want to learn more about natural hydrogen, there's a great introductory article in the February 16, 2023 issue of Science magazine now that is available online. It's kind of a long link, so I've created a shortcut link for you, which is at tinyurl.com/NatH2wells. So that's NAT H number two wells. So tinyurl.com/NatH2wells. Well, Geoff, thank you once again. I know you're such a busy guy, and thanks for your time to be with us.

[22:26] **Geoff:** My pleasure, Brian. Thank you for having me.

[22:29] **Brian:** All right. Well, listeners, if you enjoy listening to the hydrogen nowcast, consider subscribing to the podcast and also give us a rating in your podcast app. A good rating helps us be discovered by other people. And of course, word of mouth recommendations are really important. So consider letting people in your own network know about the hydrogen nowcast. Lastly, if you'd like to contact me, I'd love to hear from you. You can reach me through the website at Colorado-hydrogen.org or on Linked-In.

So until next time, this is Brian DeBruine wishing you health and prosperity. Goodbye.