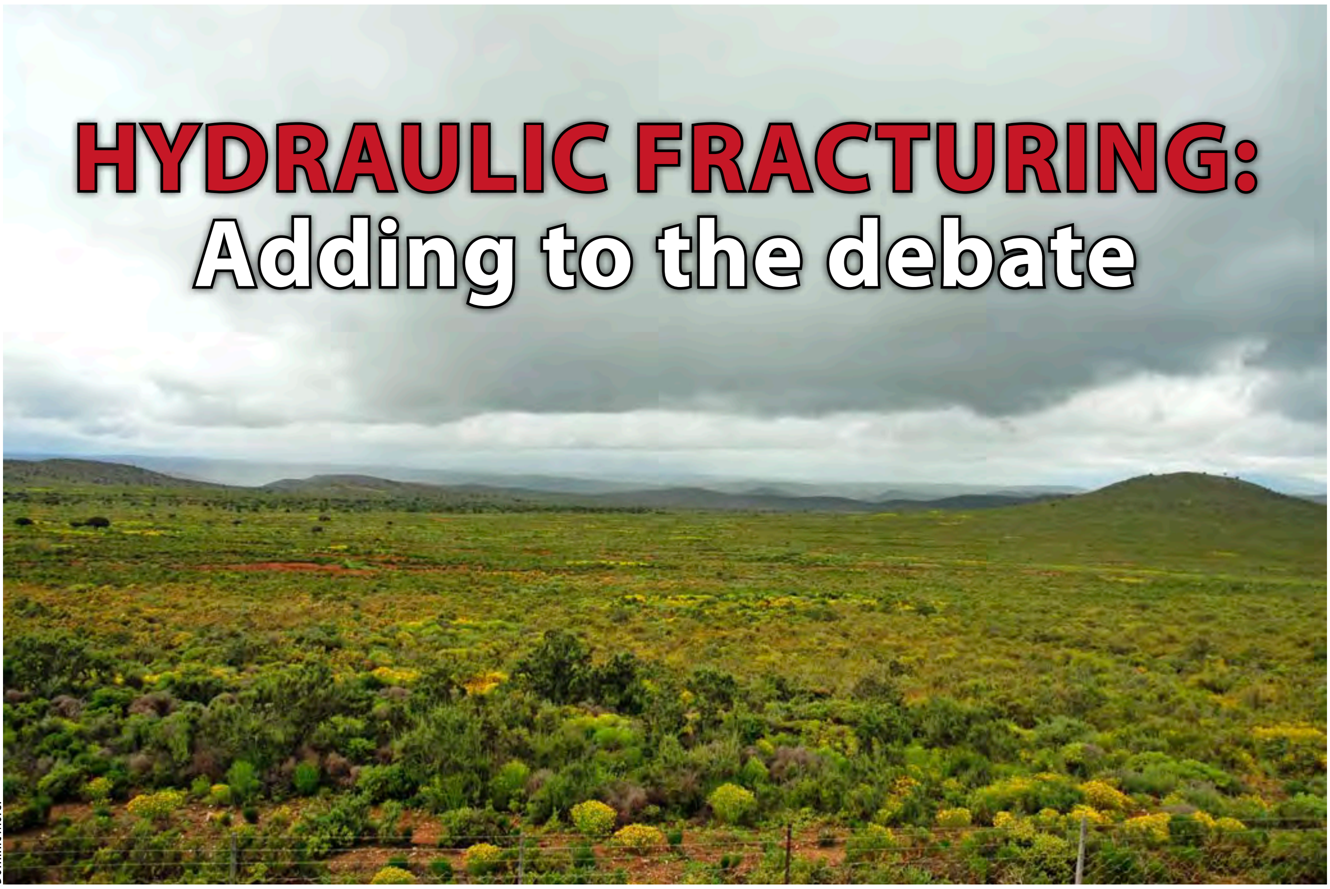
HYDRAULIC FRACTURING: Adding to the debate



Dominic Morel

A recently completed study solicited by the Water Research Commission (WRC) looks at what we know about hydraulic fracturing, and what we should know if this is allowed to go ahead in South Africa. Article by Petro Kotzé.

Since the announcement that gas exploration might take place in the Karoo, the topic has caused both elation and concern – often placing polarised opinions directly opposite to each other. On the one hand, there is the prospect of job creation and a reduced dependency on coal-generated electricity. On the other, concern has been raised that the process could pollute already scare water supplies and the pristine way of life in the Karoo.

Lack of scientific proof to back-up claims on any side of the fence has fuelled the confusion. A recent WRC report aims to fill at least some of these gaps by looking at what we currently know about the process of hydraulic fracturing, and what could happen should the process take place. Led by Prof Gideon Steyl, research fellow at the Institute for Groundwater Studies (IGS) and a Professor in Chemistry, the key issues that the report focuses on are the shale gas reservoir potential in the main Karoo basin as well as other potential areas of interest; the location relative to and relationship between the shale gas reservoirs and the Karoo aquifer systems; and the potential impacts associated with hydraulic fracturing and accompanying processes. The research group also consisted of Prof Gerrit van Tonder, Professor in Geohydrology at the University of the Free State and Dr Luc Chevallier of the Council for Geoscience.

Prof Steyl is careful to point out that the observations and findings made are neither totally comprehensive nor exhaustive, since little data is available in the public domain on hydraulic fracturing in South Africa. "We are being honest about what we know and don't, know" he says. To shed some light on the matter Prof Steyl was one of a group of researchers that visited the Marcellus shale area in the USA, where hydraulic fracturing is currently taking place. Sites visited included the Pennsylvania drill rig in Whitneyville, the fracking rig in Grover, the wellfield north of Whitneyville, the Williamsport Municipal Water Authority and the Unites States Geological Survey (USGS) office in Harrisburg.

WHAT IS IT?

Shale gas is defined as gas generated from organic-rich shale. The target gas is methane, which is an energy source and can be used for the production of fuels or as a power source for electricity generation. Methane is a dry gas and represents the final stage of hydrocarbon thermal maturation.

Organic-rich shales were originally muds deposited in marine or lacustrine basins, the organic material being derived mostly from algae, spores and pollen. These muds became buried and lithified over millions of years and generated various hydrocarbons with increasing depth of burial. Between two and four kilometres burial depth, oil is produced, between four and five, wet gas is produced and between five and six, dry gas, including methane, is produced. Deeper burial, such as what happened in the Bokkeveld Group (for example) results in low-grade metamorphism, the termination of hydrocarbon generation and the formation of graphite from the organic material. Deep core samples in the main Karoo Basin indicate that the Ecca Group shales have potential to generate dry gas south of approximately latitude 29°S.

Here, the Whitehill Formation contains the highest total organic carbon contents and presumably has the highest potential for generating dry gas. The most promising area to source gas from the Whitehill Formation is south of the southern limit of dolerite intrusion, but north of the Cape Fold Belt. In the region south-east of a line from Ficksburg to north of Laingsburg, where the top of the Lower Ecca Group is deeper than the minimum proposed depth of 1 500 m for hydraulic fracturing, shale with the best potential for dry gas lies in an east-trending zone between 30 km north of the southernmost exposures and 50 km north of the southern limit of dolerite intrusion.

These dolerite intrusions, says Prof Steyl, is what makes the South African geology unique, especially in comparison to areas where shale gas occurs in America. The intrusive dolerites are present over about 390 000 km² of the main Karoo Basin underlain by the Ecca Group (which increases the thermal maturity leading to the generation of dry gas). This causes gasification of the carbon in the shale that can only lead to gas being vented or being trapped in the sub-surface, potentially making it unavailable for hydraulic fracturing.

It is important to keep in mind that researchers only have a relative idea of the area's geology, "not an absolute" says Prof Steyl. The only way to get a clearer idea is by exploration and, he adds, even though some exploration has taken place in the area, it has not been comprehensive enough to create a clear picture of what exactly is to be found under the surface of the Karoo Basin.

HOW IS IT DONE?

During the hydraulic fracturing process, drilling starts vertically, with casing installed until a depth where all viable aquifer systems (potable water) cannot be affected. Drilling is continued for a few meters and cement pumped into the casing, until the space between the wellbore and the outer casing is entirely filled with cement.

As the vertical drilling is continued intermediate casing is inserted to stabilise the deep borehole. This also serves to isolate and separate brines and hydrocarbons which might be trapped in the sub-surface, preventing borehole interference, natural gas contamination and protection of surface aquifer systems.

At the kick-off point drilling techniques are applied to force the drilling to occur in a horizontal direction through the production zone, which can stretch for as much as three kilometres. Once the horizontal borehole has reached its target extend, production casing is installed and cemented into place to prevent leaking. Subsequently the production

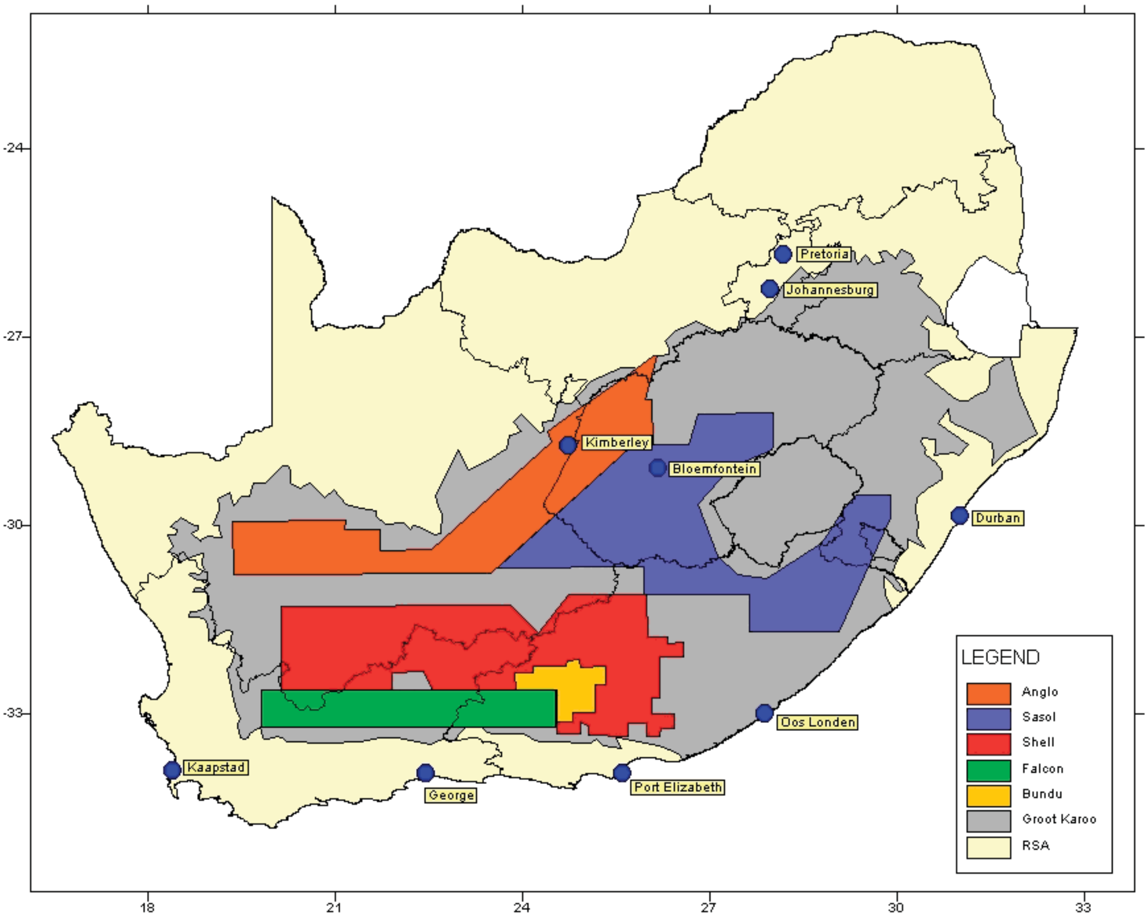
Courtesy Gideon Steyl

Above: A drilling rig near Whitneyville, which was one of the sites in the USA that researchers visited for the recent WRC research project.

Below: A clearing in the State of Pennsylvania (USA) where the pipeline for the hydraulic fracturing is running.

Courtesy Gideon Steyl

There are currently a number of companies that have exploration rights to investigate natural gas resources in Karoo type formations. The area available for natural gas development is substantially larger than just the Karoo, with exploration areas covering six of the nine provinces in South Africa. A five-spot pumping test in the Waterberg has been operated since 2004 by Anglo Operations and 20 boreholes have been drilled in the main Karoo since the beginning of 2008 to test for coal-bed methane production potential. Most of the exploration rights for natural gas resources have been allocated for shale gas development.



casing is punctured at selected points where fracturing fluid will be pumped through at increased pressures to release the shale gas. This method (hydraulic fracturing) is commonly used to enhance the production of low permeability formations such as tight sands, coal beds, and deep shales.

The chemical composition of the fracturing fluid, as well as the rate and pressure at which it is pumped into the shale, are tailored to the specific properties of each shale formation and, to some extent, each

'Fracking' can be a confusing term since the term actually implies two very different processes. Hydro fracturing refers to the process of fracturing with water only, while hydraulic fracturing refers to fracturing using water with a chemical mixture.

The main concerns regarding the possible impacts of hydraulic fracturing on the environment (main concerns indicated in red).

borehole due to differences in volume. When the pressure increases to a sufficient level, it causes a hydraulic fracture to open in the rock, propagating along a plane more or less perpendicular to the path of the borehole direction.

There are a number of concerns regarding hydraulic fracturing, of which eleven were identified in the report. Should the process be approved, regulation to prevent environmental damage is the most important success factor, says Prof Steyl. A major concern in natural gas development is the prevention of migration of gas or other fluids out of the reservoir and into overlying strata, particularly fresh water aquifers. In cases where this has occurred, according to the report, it has been the result of well construction problems and not of hydraulic fracturing itself.

Water use, especially in a water-scarce area like the Karoo, is another major distress factor. A fracture treatment of a typical Antrim gas well, as located in Antrim, Michigan requires about 50 000 gallons (189 m^3) of water. This amount can increase to as much as 5 000 000 gallons (18 927 m^3) or more, the same amount typically used by eight to ten acres of corn during a growing season.

Proper management of produced water is particularly essential in protecting public health and the environment, says Prof Steyl. In Michigan, for example, produced water must be managed and disposed of according to strict rules.

Accept for these three concerns, identified as the most probable points of impact, other main issues include the migration of gas, the management of produced water and the identification of chemical additives. Spills of chemical additives or flowback water can have adverse environmental or public health impacts.

The application of good management practices would significantly reduce these events from occurring. Additionally, monitoring by the regulatory body would ensure a continuation of good practices and, notes Prof Steyl, the monitoring team must be independent from the State, even though fines would be paid to the State. Ideally, such a team must consist of water, terrain and drilling specialists.

RECOMMENDATIONS

"The most important conclusion from this report is regulation," stipulates Prof Steyl. "What is pumped in and out, the remediation and handling of the terrain and even water purification should be closely monitored."

For example, Michigan's laws and rules effectively protect water and other natural resources as well as public health and safety from potential adverse effects of hydraulic fracturing. Their Department of Environmental Quality has more than 50 staff employed in enforcing these state requirements and is taking a proactive approach in


Courtesy Gideon Steyl

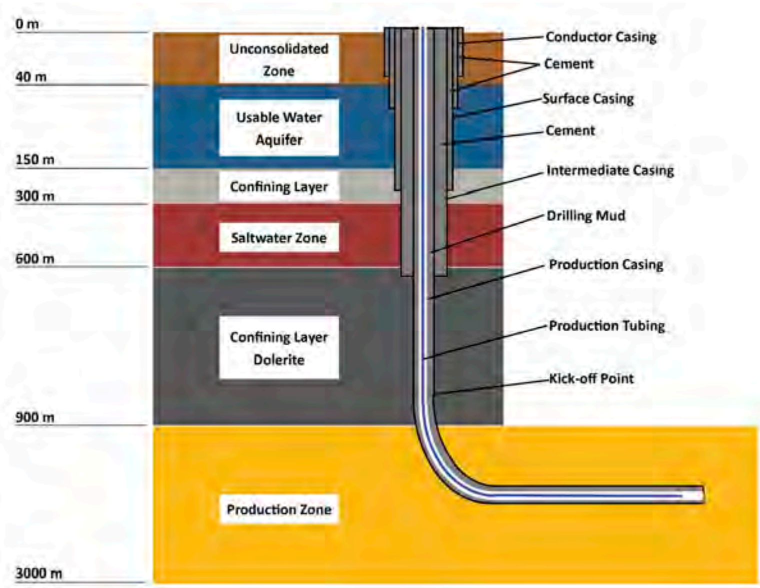

Courtesy Gideon Steyl

Below: *A hydraulic fracturing operation with a Christmas tree blow-out preventer system in the middle of the picture, while the chemical components delivery system is on the right-hand side and one perforation transport truck is stationed on the left-hand side.*

Top: *Hydraulic fracturing drilling operations taking place at Whitneyville.*

Above: *The water containment facility on a hydraulic fracturing site consisting of 56 large containment vessels.*

Courtesy Gideon Steyl



***Left:** A conceptual model of borehole drilling arrangement for gas exploration.*

Courtesy Gideon Steyl

***Bottom left:** The production facilities during the remediation of the site. Additional water containment facilities are shown in the background which will be removed before full production commences.*

Courtesy Gideon Steyl

***Below:** A pond facility on site with geotextile liner and moundings. The research report recommends that these facilities should not be used in the South African environment.*

addressing large-scale hydraulic fracturing as well as other issues associated with deep shale gas development.

Should the hydraulic fracturing process be used and allowed by the government of South Africa, the most critical recommendations to be followed are:

- No chemicals should be injected into the boreholes without full disclosure of the type of compound used.
- Waste pits should be avoided as far as possible.
- Drilling should be conducted at least 10 km from any residential areas.
- Drilling logs should be filed at the Department of Water Affairs (DWA) and Department of Environmental Affairs (DEA), and should be publically available within six months of drilling completion.
- Only best-practice guidelines should be implemented.
- A pilot study should be done a year in advance in which a monitoring network of boreholes (both shallow and deep) is installed to monitor the impact of hydraulic fracturing on the area.
- A baseline should be constructed before any drilling is done in an area, and should include atmospheric, soil, surface water and groundwater (isotopes, macro, micro and metal species) environments. It should be filed at the DWA and the DEA, the results verified by an independent body and the data be made available to the public (this is one of the greatest drawbacks in the international arena).
- All associated drilling footprints, including return water containment structures should be fully remediated to natural levels before the contractor is allowed to leave the site.
- Wastewater containers should be used to store and transport wastewater from the site to a suitable water treatment plant that can correctly purify the water.
- Strict legal licensing restrictions should be applied by the government in which the licence for drilling is leased to the drilling company.

Nevertheless, many questions remain. It is still unknown what the potential for shale gas extraction is or what the effect of our unique geology will be on such a project. A pilot study which involves exploration and drilling by an independent body of researchers could be an answer, concludes Prof Steyl.

The final WRC report, *State of the art: Fracking for shale gas exploration in South Africa and the impact on water resources* (**Report No. KV 294/11**) will become available later this year. ❑