The art to drilling in Brazil

Denis Pellerin, Horizontal Drilling International S.A., France, José Edoardo Jardim, Intech Engenharia Lda, Brazil, report on the use of horizontal directional drilling to cross quartzite ridges during the Bolivia - Mato Grosso pipeline project in Brazil.

When GasOcidente do Mato Grosso, a Brasilian company owned jointly by Enron and Shell, initiated studies for the construction of the 200 km long Bolivia - Mato Grosso gas pipeline to supply the new Cuiaba power plant, they faced a great technical challenge spread over 1/3 of its length: a series of mountains in the Serrana Province, Brazil. The mountains are in an environmentally sensitive area and present a special geomorphology with very steep relief, limiting to the east the Pantanal Matogrossense area. The project team faced a great engineering challenge in crossing the crests of some of the mountains in the Serrana Province.

The conventional method for laying the gas pipeline would have involved opening 30 m wide servitude belts, grading the surface and excavating a trench 1 - 2 m deep across very steep and fragile mountains that are susceptible to rapid erosion during the rainy seasons. Therefore, the decision to use a different method was made and one solution studied for the three steepest ridges was to drill horizontal directional wells below the top 1/3 of the mountains, classified as areas of permanent preservation.

Comparative analysis between this and various alternative methods and the environmental impacts of each lead to the horizontal directional wells being the most appropriate method for crossing the Piraputanga, Cachoeirinha and Palmeira ridges (Figure 2).

Great concerns with preserving the environment existed during this project and detailed preparatory surveys led to some corrections to the original plan of the gas pipeline route, particularly related to preservation of fauna living in the caves. Special attention was given to the reallocation of orchids in the servitude belt, but erosion problems in steep scarps to lay down the gas pipeline by conventional methods and preservation of water springs brought constant concern. Another major concern was the speed of construction. By Summer 2000, the power plant in Cuiaba was near completion and two thirds of the

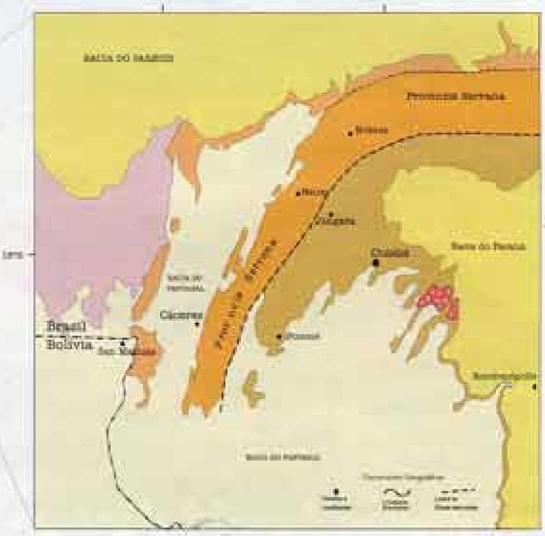


Figure 1. A simplified geological map and location of the ridge section in the Serrana province, Brazil.

Figure 2. Serrana província ridges: 1) Piraputanga, 2) Cachoeirinha and 3) Palmeira.

pipeline had already been built, including four drilled river crossings. Only the 60 km stretch across the ridges was still under construction when the directional drilling contract for the three main ridges was awarded to the Horizontal Drilling International S.A (HDI)-Intech consortium in July 2000.

The Piraputanga ridge

Work on the first of the three ridge crossings began in late August 2000 and, at this time, only very limited soil information was available. Two 25 m deep boreholes in the vicinity of the planned entry and exit locations showed alternate layers of sandstone and shale with unconfined compressive strength (UCS) below 860 bars. The geological bibliography that was available confirmed these results.

HDI chose to drill two 850 m long parallel holes with a classic arc shape, the second one to be used as a mud return line during the hole opening operations on the first hole. A little less than half of this crossing included drilling through quartzite that proved extremely abrasive and hard. Samples recovered from the hole were tested in two different laboratories and showed UCS of 2500 - 3215 bars (35 000 - 45 000 psi). Consequently, the quality and number of drill bits, as well as hole opener cutters and arms, were adjusted in order to overcome the extremely rapid wear on the tools.

Additionally, the holes intercepted a reserve of meteoric water in a fractured zone underlayed by impermeable shale. As this was not expected, it took the project team by surprise and the volumes of drilling fluid increased exponentially because of the dilution. However, the problem was solved by drilling the hole for the mud return line higher than the first hole for the product pipe. Thus, it acted as a drain for the fresh water which could then be channeled to the river in the valley without being mixed with the bentonite mud. The other hole could then be reamed with reduced interference from the underground water. The Piraputanga ridge crossing was finally pulled in less than six hours after 127 days of continuous work around the clock.

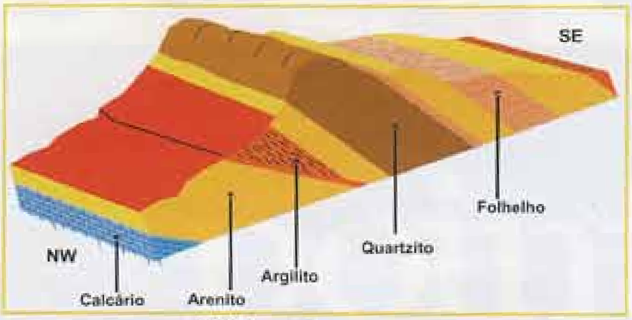


Figure 3. A geological section of the Cachoeirinha ridge, showing the stratigraphic sequences of shale, sandstone and quartzite.

Figure 4. Preperation of the pipe column to be pulled along the horizontal directional well.

Rethinking the project

In view of the first crossing, significant rethinking occurred in order to accelerate the works on the two subsequent ridges. These two ridges were in much more remote locations and significant numbers of personnel and equipment were mobilised on site in order to work simultaneously on both sites. Two complete HD 850 drilling spreads (pull 2500 kN and torque 140 000 Nm) were operational and additional pumping capacity was mobilised. The personnel involved now amounted to 95 people and two site camps had been installed near the drill rig locations. Works would continue to be carried out 24 hrs per day.

The main question that remained was what would be found inside these two ridges. Again, two test holes had initially been sunk in the vicinity of the planned entry and exit sites. Additionally, HDI-Intech organised a survey of the surface of the ridges with qualified geologists and hydrogeologists. The classification of rock samples collected on the surface, as well as the observation of the inclination of surface cracks and fractures, allowed the team to prepare geological cross sections of each ridge. Based on these results, the project team developed the drilling programs and tools in adequate quality and sufficient quantity were dispatched to the drill sites.

The drilling profiles were also adjusted, in order to make better use of gravity to flush the cuttings out of the hole. The pipe side exit points were chosen 38 m and 75 m higher than their respective entry points on the other side of Cacheirinha and Palmeira ridges. The plan was to drill only with water and to drill only one hole at each location, forward opening the hole from the rig to the pipe side, in order to force the water flow to the drill site where the separating unit could filtrate the waters. The contract itself was also redesigned, in order to include performance incentives as well as safety incentives so that safety would not be sacrificed for speed of execution.

The Cachoeirinha ridge

The geological profile and drilling column developed by the geologists proved very accurate (Figure 3) and the 943 m long pilot hole drilling was executed well and ahead of schedule.

For the forward hole opening, HDI-Intech crews used a dozer in the slope of the pipe side to keep the drill string in tension and apply the weight on the hole opener cutters. Despite the increased pumping capacity, the transport of cuttings along the hole became a problem after a third of the length. At this position the hole had regained the altitude of the entry point and beyond that point the hole was dry, with the water running down to the wet section each time the pumps were stopped. The result was an accumulation of cuttings at the transition and down to the bottom of the hole, demanding several cleaning passes.

As a consequence, the drilling crews still experienced tool failures during hole opening, especially during trip out/trip in operations to change worn out tools, and became expert at handling fishing tools of various sizes and shapes. Trip out/trip in times were also increased in comparison to the Piraputanga ridge crossing because the 380 m thick quartzite layer was located in the center of the ridge, starting 300 m away from the drill site, while it was starting almost at the rig in the case of Piraputanga.

In the mean time, the 450 mm pipestring was welded, coated and hydrotested in one string in the bottom of the adjacent valley and conveyed to the drilled exit point. A launching ramp, 14 m high in some points, was implemented in order to bring the pipe string to the hole with the adequate angle.

Finally, on day 93, the Powercrete coated pipestring was pulled very easily and with very low forces, just four days behind schedule.

The Palmeira ridge

Again the geological profile and drilling column developed by the geologists proved very accurate and identified two thick quartzite layers covering the first half of the crossing almost completely.

The Palmeira ridge crossing was located in an extremely remote location, and it took a full month and a half to move the complete spread uphill and install the equipment, on three different platform levels.

In light of the Piraputanga crossing, already well under way at that time was, HDI-Intech opted for a straight uphill crossing with an angle of 5° in order to limit cutting deposits along the profile. The decision was also made to still drill the pilot hole only with water, although the likelihood of intercepting a storage of meteoric waters was judged very low by the hydrogeologist expert in consideration of the altitude chosen for the crossing and the sequence of the rock layers observed at the Palmeira ridge.

Again, both pilot hole and hole opening operations went well, although with a few tool failures still occurring. Trip out/trip in times to change worn out tools were low as the quartzite layers were located near to the rig side of the ridge. Overall, all operations were well ahead of schedule and, as expected, the profile did not intercept any water storage and it was possible to use bentonite based mud on the second hole opening. This greatly improved the transport of cuttings. Finally, the 877 m long pipe string was succesfully pulled 48 days after spud in, a week before the Cachoeirinha string was pulled. Consequently, the whole drilling project was ahead of schedule and, on 14th July 2001, the first gas reached the Cuiaba power plant.

Conclusion

At all times during the execution of the work, there was a great concern with the preservation of the environment. The contracting and contracted parties involved in the project, continuously trying to minimise the impact on the nature. As a result, appropriate planning and rigorous following up of the operations contributed to both dealing with the foreseen and unexpected problems, while preserving the local vegetation and fauna at the same time.

Some positive aspects should be emphasised regarding the application of the horizontal directional drilling technology, such as preservation of the flora, non interruption of mobilisation of the fauna, minimisation of the duration of the operation, concentration of the support services to platforms with limited space, absence of great excavation or embankment volumes, dismissal of the re-vegetation and preservation of the top of the mountains (area of permanent preservation according to legislation). Even the risk of damaging the aquifers proved to be restricted and manageable. The levels of recharge are expected to recompose very quickly thanks to the coarse clastic and structural characteristics of the rocks forming these mountains. However, the meticulous evaluation of possible interference with aquifers, accompanied by a meticulous monitoring and environmental control of the operations allowed the execution of the directional horizontal drillings with minimal environmental impact.

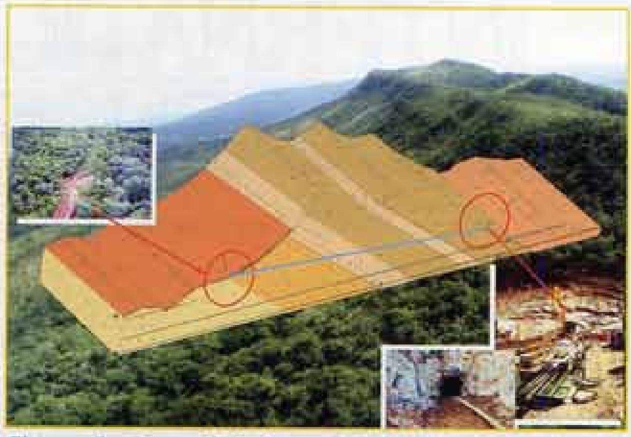
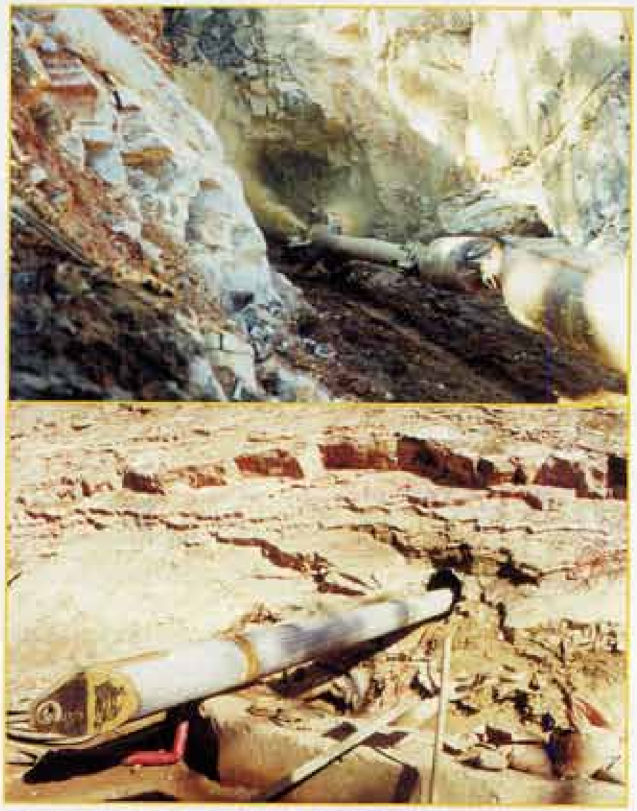


Figure 5. An aerial view of Palmeira ridge and the schematic geological section showing the entry and exit points of the well in detail.



Figures 6 and 7. Pipe pulling operatons.

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