4D Seismic Analysis and Reservoir Management at Christina Lake*

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Abstract

Integration between the geosciences and reservoir engineering is a key component in oil sands resource recovery. This paper will show how integration between time-lapse seismic analysis and reservoir optimization techniques in Cenovus Energy's Christina Lake property have helped in developing the resource in an efficient and sustainable manner. We will explore how the use of 4D seismic data, reservoir saturation logs, and temperature logs have helped in identifying barriers to steam and steam growth patterns. Furthermore, we will discuss how we have integrated our 4D seismic results with different completion designs and operating strategies. Our findings provide essential information that is used for production forecasting, simulation, and reserves auditing.

4D Seismic Overview

Time-lapse (4D) seismic monitoring is accomplished by recording surveys over the same field at different stages of development. The acoustic/elastic properties of the reservoir change with production and injection processes. The seismic information from these surveys can therefore show the areal and vertical extent of these processes. At Christina Lake, Cenovus has used this technique since the start of SAGD production. It has provided engineers and geoscientists with valuable information of steam chamber growth and geologic heterogeneities. Figure 1 and Figure 2 show the seismic RMS amplitude differences over a producing pad for two separate time-lapse surveys at two different times. These maps provide information on the effectiveness of steam injection design and show where the steam chamber has stalled or not reached the reservoir.

In order to calibrate the time-lapse amplitude differences with development processes, we have deployed several borehole tools that measure important reservoir properties such as temperature and fluid saturation. In conjunction with the 4D seismic, these help geoscientists and engineers in calculating the steam chamber geometry and in identifying gas caps that develop out of solution from bitumen production.

Engineering Applications

Steam chamber conformance in our SAGD well pairs is crucial when calculating resource recovery factors (Figure 3). It gives the operator confidence that the reservoir along the SAGD well pair is being developed and thus, provides reserves auditors with important information for calculating the recoverable reserves estimates. Depending on reservoir quality, having 100% steam chamber conformance demonstrates efficient well production techniques and complete resource recovery.

At Christina Lake, 4D seismic along with thermocouple data is used to determine with great accuracy how current production techniques are affecting steam chamber conformance. This allows engineers to change injection design accordingly. After implementing new injection techniques, such as steam subs, the steam conformance has been observed to improve.

Figure 4 shows the temperature data for an observation well along B013 well pair with the time-lapse seismic RMS amplitude map for the January 2010 monitor survey. Both show poor steam chamber development at the well location, while at the heel and toe of the laterals the steam chamber is seen to develop properly. After switching to steam sub injection method, which allows for four-injection points down-hole, the temperature at the observation well is seen to increase on the temperature logs from February to November 2010. This increase in steam chamber growth was also observed on the next monitor 4D seismic survey, which was shot in January 2011 (Figure 5).

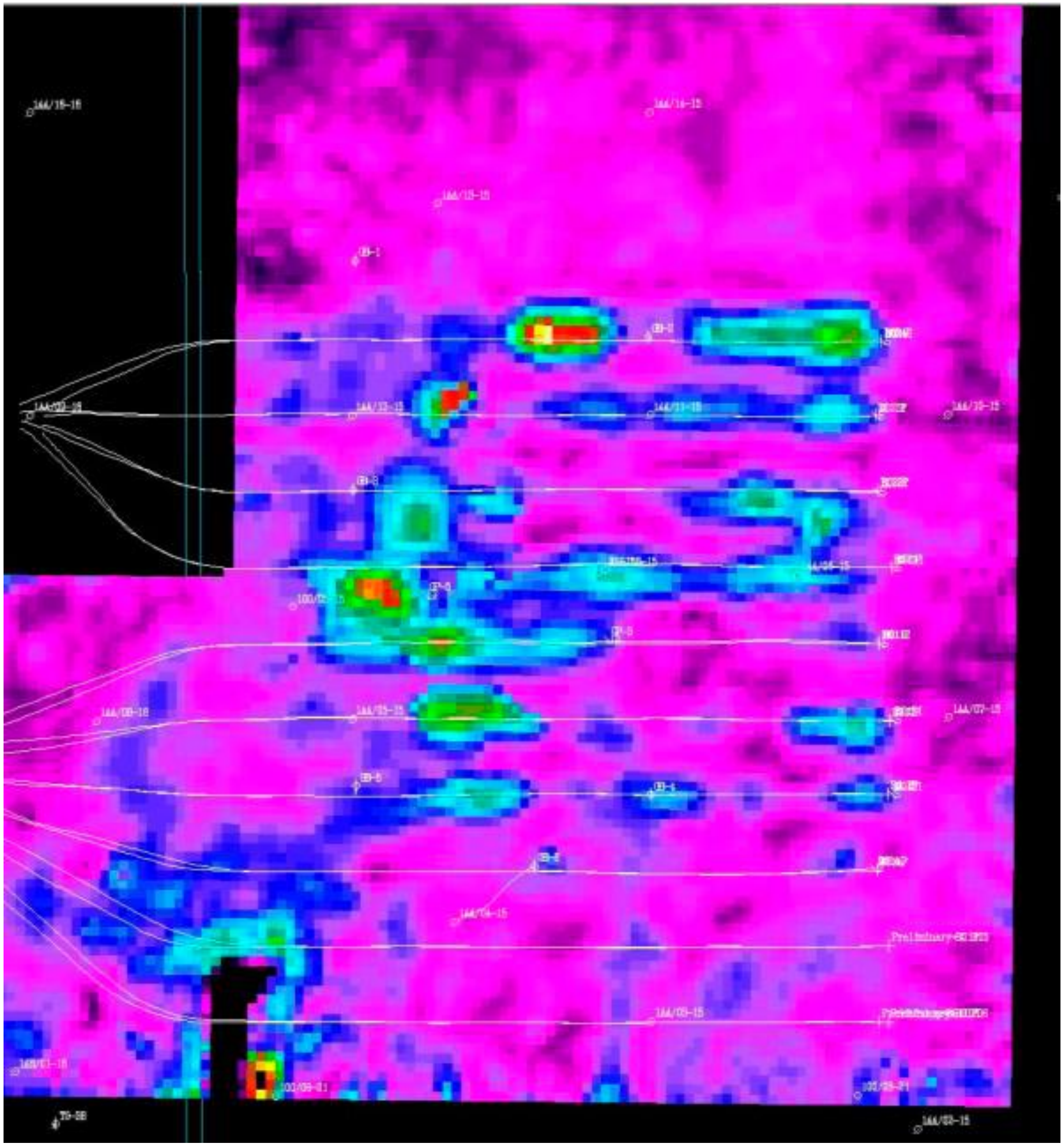

Figure 1. RMS amplitude difference of 2006 baseline with 2009 monitor surveys.

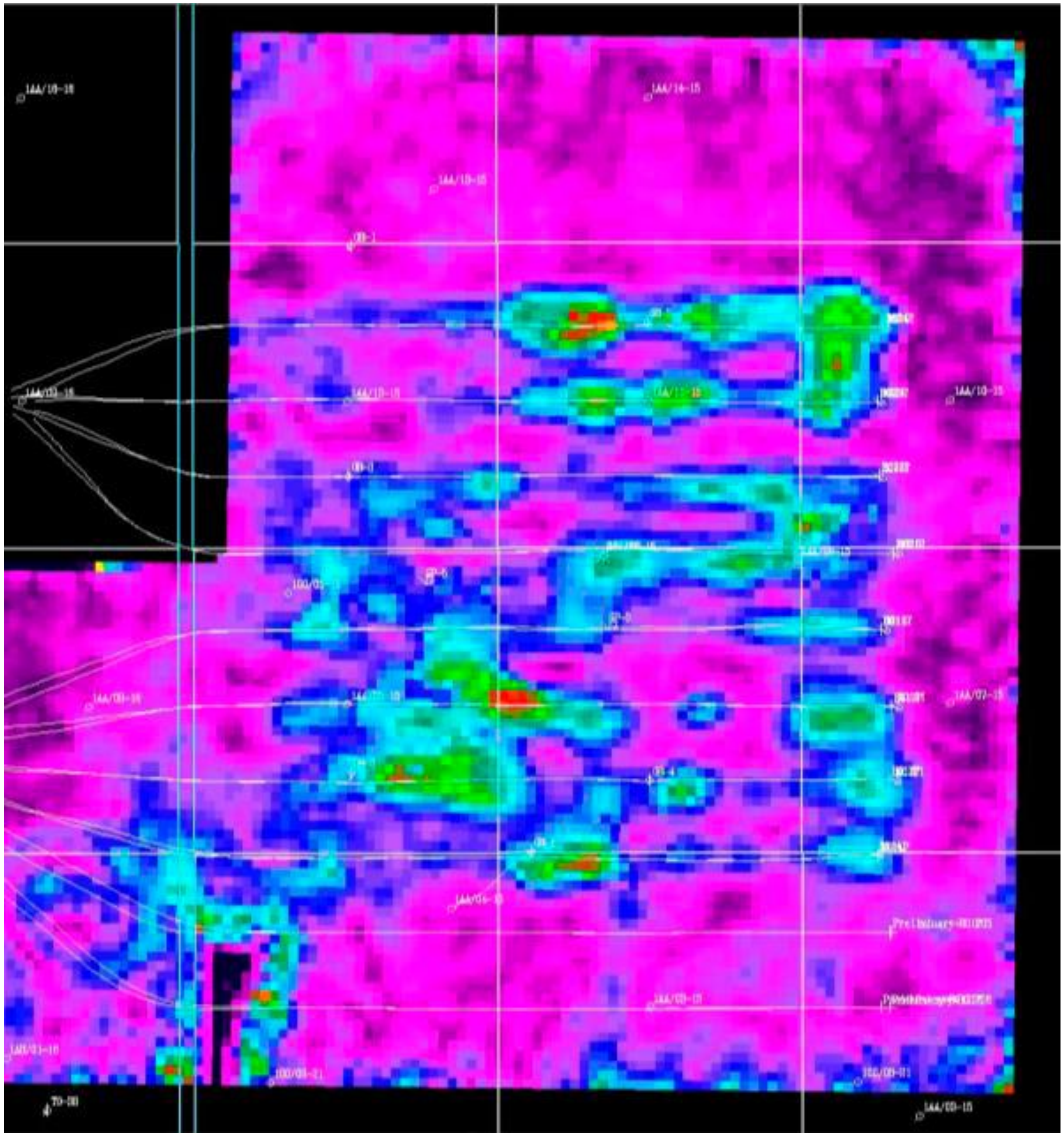

Figure 2. RMS amplitude difference of 2006 baseline with 2010 monitor surveys.

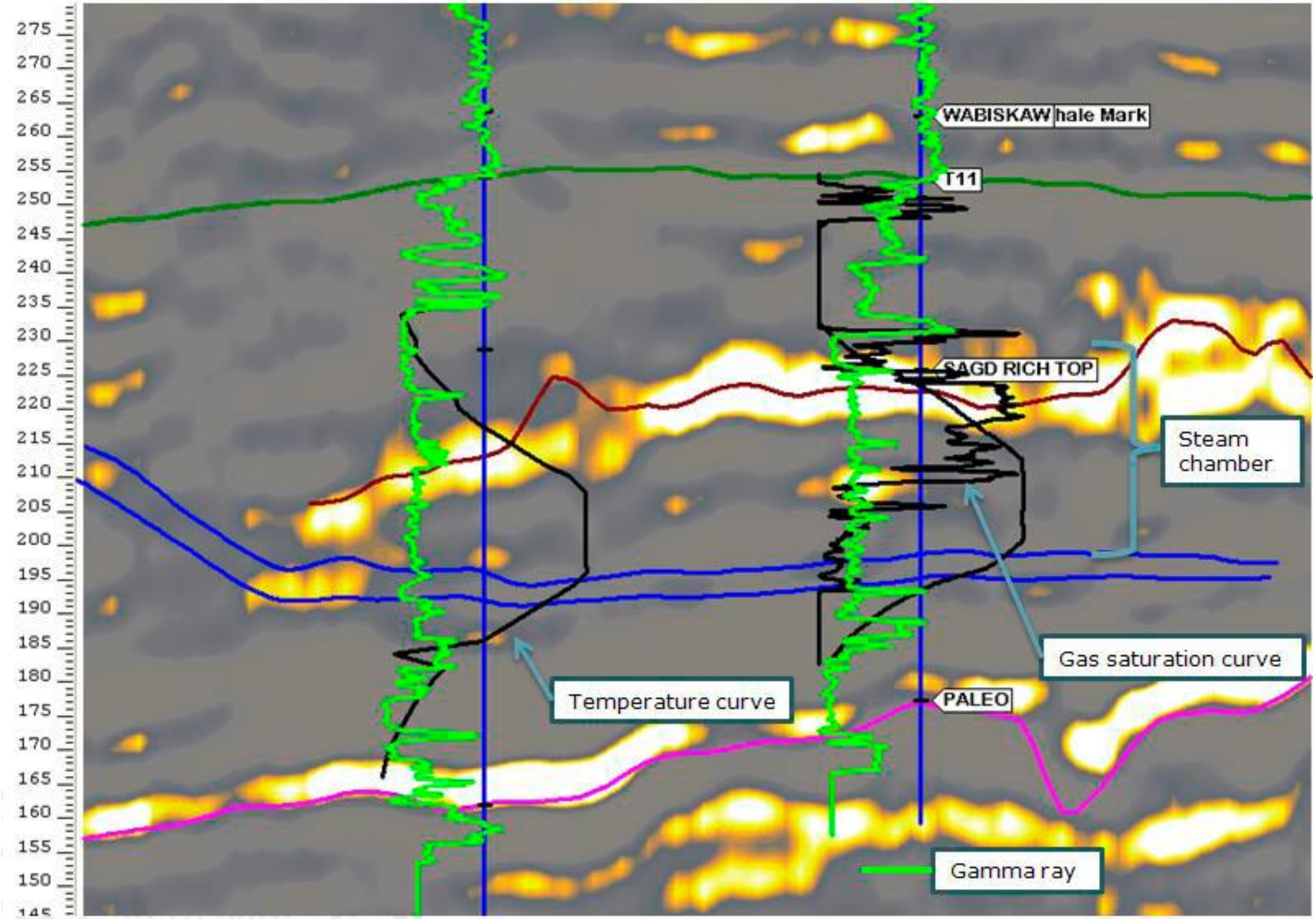

Figure 3. Producer and injector laterals with developing chamber.

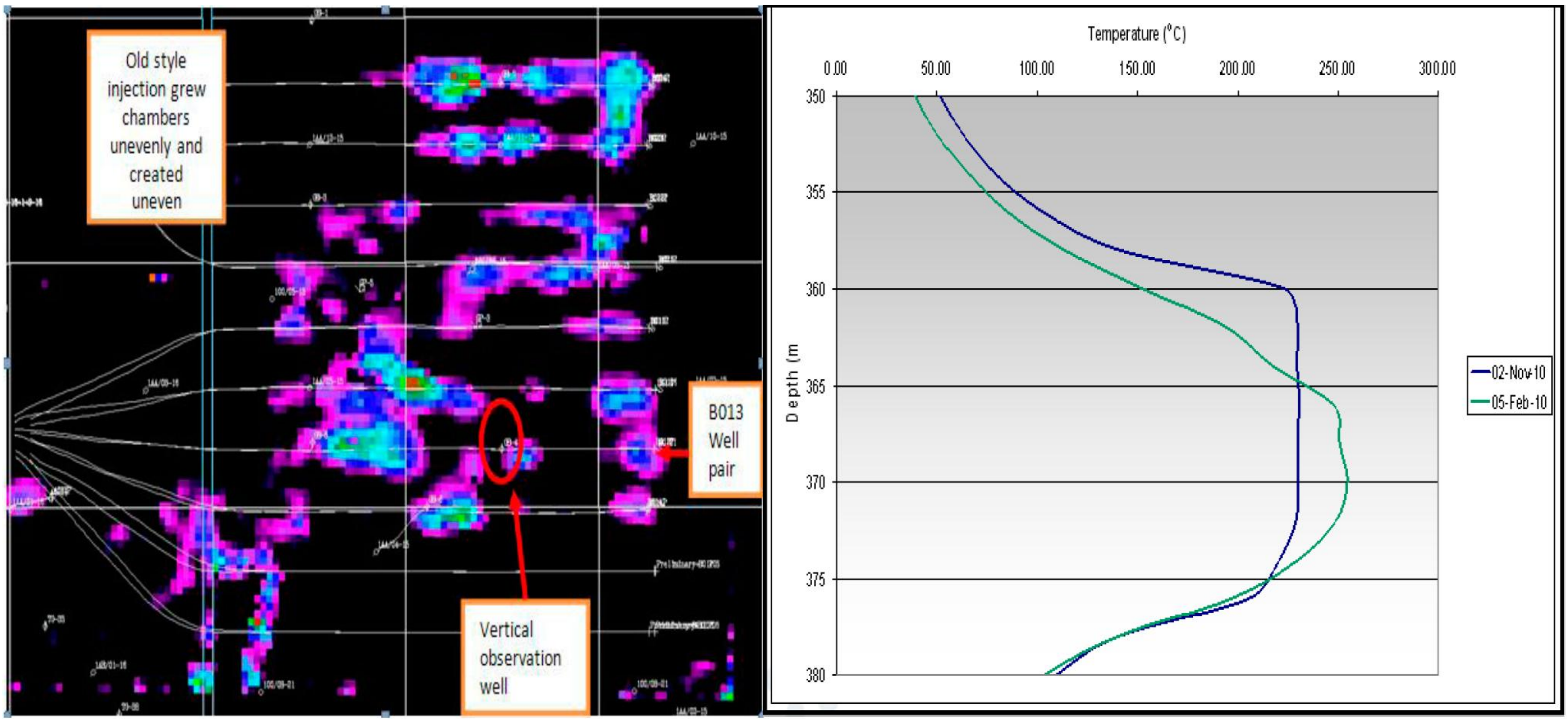

Figure 4. Time-lapse seismic RMS amplitude for the Jan-2010 monitor survey showing lack of steam conformance with temperature logs from the observation well before and after new injection methods.

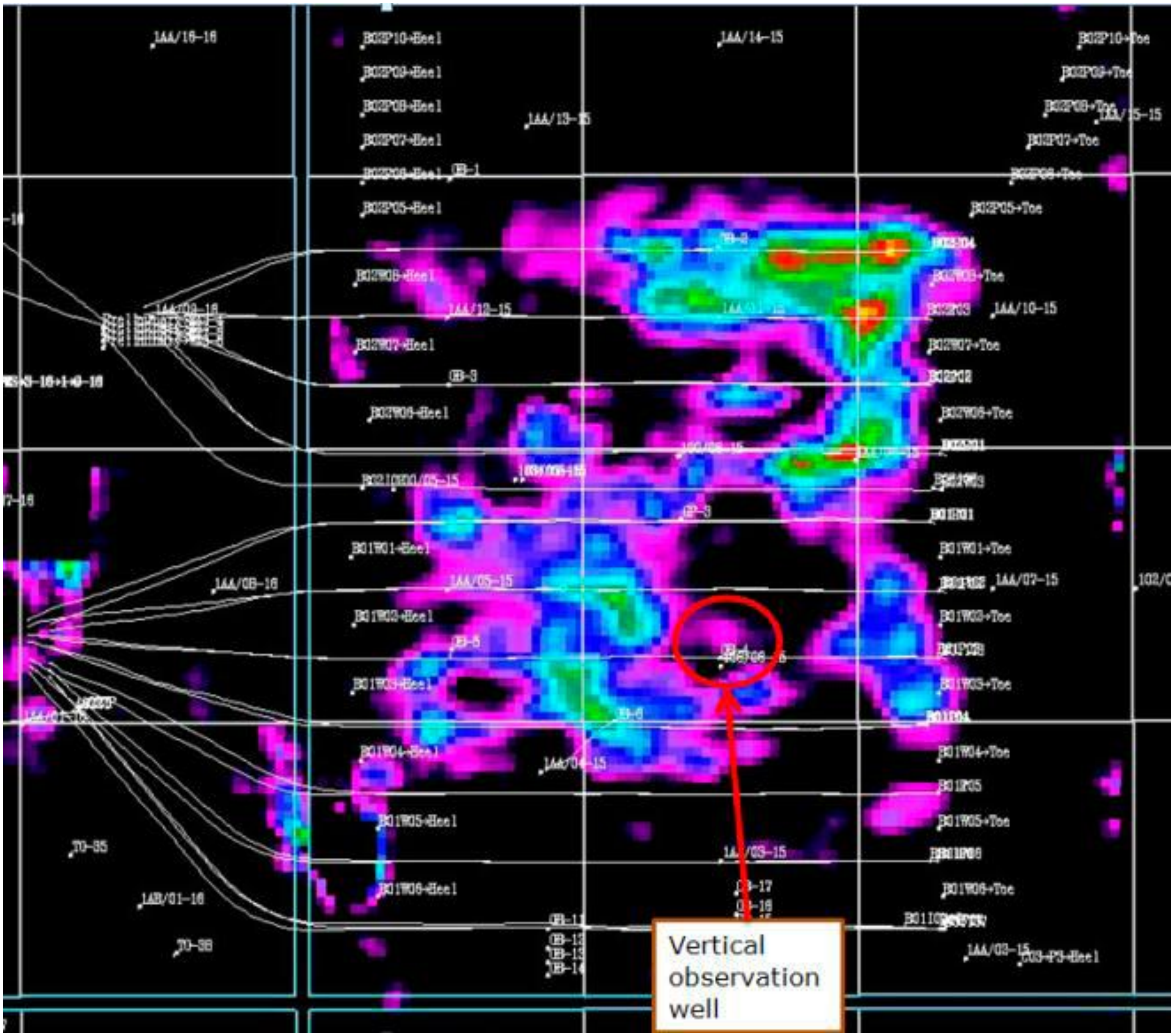

Figure 5. January 2011 monitor 4D survey shows increase in steam chamber conformance.