The Importance of Ground Water Aquifer Identification on Well Planning: An Example from the São Sebastião Aquifer, Northeast Brazil*

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Abstract

São Sebastião aquifer is located in the Recôncavo Basin, northeast Brazil, and it is one of the most important fresh-water reservoir in the state of Bahia. Currently, it is forbidden to drill wells using oil-base mud in fresh-water zones, as had been done before. Thus, the understanding of the ground-water-aquifer distribution is important to predict the bottom of the fresh-water zone prior to drilling. The Recôncavo aquifer system was identified as two different components:

(1) The ground water resources, composed of Barreiras and Marizal formations, and the upper layers from São Sebastião Formation. This system is an open aquifer that allows the vertical water flow from surface down to the São Sebastião Formation.

(2) The subsurface water resources are multiple layers in a confined system composed of the São Sebastião Formation, which iss up to 1600 m in thickness.

The fresh water in Recôncavo is classified as very good quality. A map of the bottom of fresh-water zone was created for the entire Recôncavo Basin, and the aquifer depths range from 0m to 1600m. Higher thicknesses are found mainly in the Alagoinhas Miranga and Camaçari structural lows. The aquifer host formations were eroded at some of the structural highs of Recôncavo, mainly at the east margin and northernmost compartment of the basin. Thus, there is no subsurface fresh-water resource in these areas, but some shallow ground water can be found if there are sandstones from the syn-rift stage formations near the surface.

Alvopetro Energy has drilled four wells, one of which was drilled before this study, while the other three were drilled after. In the first well, the fresh-water bottom was detected 57m deeper than the estimated. In the three other wells drilled after this study, Alvopetro Energy was able to reduce the discrepancy to a maximum of 5m. The identification of fresh-water distribution is extremely important for well-drilling planning, as it is essential to determine the surface casing depths in a correct location to be successful in isolating all subsurface aquifers before changing the drilling mud from water to oil base. Aquifer mapping is supporting Alvopetro Energy's efforts to reduce significantly the error on estimating the bottom of the fresh-water zone in drilling operations. Greater precision in the fresh-water aquifer determination increases the drilling performance, reduces the operational risks, and increases the confidence of the environmental department in the company operations.

Introduction

The São Sebastião aquifer is located in the Recôncavo Basin, northeast Brazil (Figure 1), and it is one of the most important fresh-water reservoirs in the state of Bahia. Responsible drilling practices, along with the environmental department of the state (INEMA), focus on the preservation of fresh-water resources. Currently it is forbidden to drill wells using oil-based mud in fresh-water zones, as had been done before. The fresh-water zone must be drilled using water-based mud, the surface hole cased and cemented, and then casing and cement integrity tests performed before oil-based mud, which is required for deeper hole-stability issues, may be used. The understanding of the ground-water aquifer distribution is fundamentally important to protecting the fresh-water resources by accurately predicting the base of the fresh-water zone prior to drilling, thus avoiding operational issues, environmental damage, and penalties.

Another environmental concern in Brazil is the unconventional hydraulic fracture stimulation, which is under intensive study by the environmental department, where one of their main concerns is to protect fresh groundwater from contamination caused by these activities.

The Recôncavo fresh-water aquifer system is divided into two different components; the ground water and the subsurface aquifer systems. (1) The ground-water resources are composed of the Barreiras and Marizal formations (post-rift deposits with maximum thicknesses of 60m and 240m, respectively), combined with the upper layers of the late-rift São Sebastião Formation (Figure 2). This system is an open aquifer that allows vertical water flow from the surface down to the upper layers of the São Sebastião Formation. (2) The subsurface water resources are multiple layers in a confined system within the São Sebastião Formation, which is up to 1600 m thick in the central part of the basin. The subsurface water system in the Recôncavo Basin is also classified as very good quality; however, the salinity variation in the deepest parts of the aquifer is not well known.

Objectives

The main objective of this study is to map the distribution of the fresh-water resources in the Recôncavo Basin, to identify and predict the bottom of the fresh-water zone in support of protecting the fresh-water resources. Accurate prediction of the depth that the surface casing must be set is key to avoiding extra cost. Failure causes several operational issues associated with drilling the surface hole deeper or shallower than the top of the Pojuca Formation. Certifying that all fresh-water zones are isolated and protected before using oil-base mud and avoiding significant exposure of the Pojuca Formation to water-based mud are key objectives in drilling operations. This study will also support the environmental licensing for hydraulic fracture stimulations.

Procedures

To perform the study wireline log data from 330 wells were used, distributed all over the Recôncavo Basin. The selected wells all had resistivity curves over the base of the São Sebastião Formation to identify the base of the fresh water. In this basin, the base of the fresh water is identified by an abrupt decrease of the resistivity curve, usually due to the change from São Sebastião Formation fresh water to the salty water from Pojuca Formation (rift deposits) (Figure 3).

Usually, the base of the São Sebastião Formation matches the base of the fresh-water aquifer, but not for all the wells. In some wells, the fresh water changes to salty water within the São Sebastião Formation and generates confusion when picking the top of the Pojuca Formation. For the purposes of this mapping project, the base of the fresh-water zone was used, independent of whether or not it coincides with the formation boundary. Once the well data were interpreted, the map was gridded using IHS Petra software using Highly Connected Features as interpolation method.

Results

A map of the bottom of fresh-water zone was created for the entire Recôncavo Basin. The aquifer depths range from 0 to 1500m (Figure 4). Higher thicknesses are found mainly in the Alagoinhas, Miranga, and Camaçari structural lows (Figure 1(b)). In these lows, the higher subsidence rates during the late-rift stage have allowed the deposition and preservation of a thicker São Sebastião Formation, which has an average thickness of 1000m. The aquifer host formations were eroded off some of the structural highs of the Recôncavo Basin, mainly on the east margin and the northernmost compartment of the basin. As a result, there is no large subsurface fresh-water resource in these areas, but some shallow ground water can sometimes be found if there are sandstones from the syn-rift stage formations near the surface. These sands with original salty formation waters became flushed with fresh-surface waters; however, the water quality of such ground-water resources is not as good.

Alvopetro Energy has drilled four wells over the last 2 years, one of which was drilled before this study, while the other three were drilled after. In the first well, the fresh-water bottom was detected 57m deeper than the estimated depth. In the three other wells drilled after this study, Alvopetro Energy was able to reduce the discrepancy to a maximum of 5m.

Conclusions

The preservation of the ground fresh-water resources is part of Alvopetro’s mandate as a responsible operator. The identification of fresh-water distribution is extremely important for well planning, as it is essential to determine the surface casing depths correctly at a location to be successful in isolating all the ground water and subsurface aquifers before changing the drilling mud from water- to oil-base. Drilling the surface hole much deeper than the base of the fresh-water zone is not a good alternative because the water-base mud reacts with the Pojuca Formation shales causing drilling issues, such as stuck pipe.

Aquifer mapping is supporting Alvopetro Energy´s efforts significantly to reduce the estimation error of the base of the fresh-water zone for drilling operations. Greater precision on the fresh-water aquifer determination increases the drilling performance, increases the confidence in drilling programs, reduces the operational risks due to the reactive Pojuca Formation shales, and increases the confidence of the environmental department in the company operations.

Acknowledgements

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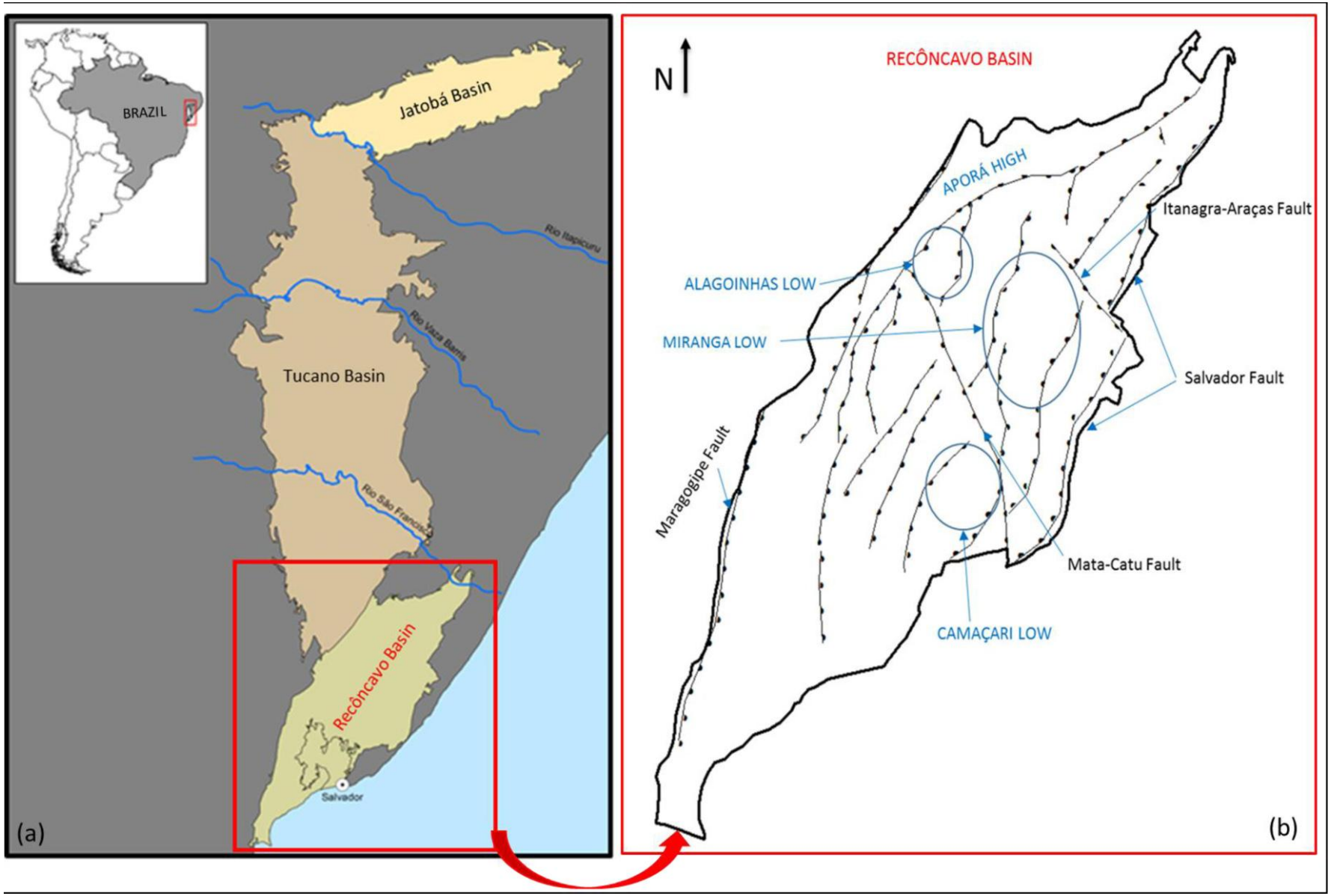

Figure 1. (a) Location of Recôncavo-Tucano-Jatobá intracontinental rift system in northeast Brazil. (b) Main pre-rift rift level structures of the Recôncavo Basin. Structures modified from Milhomem et al. (2003).

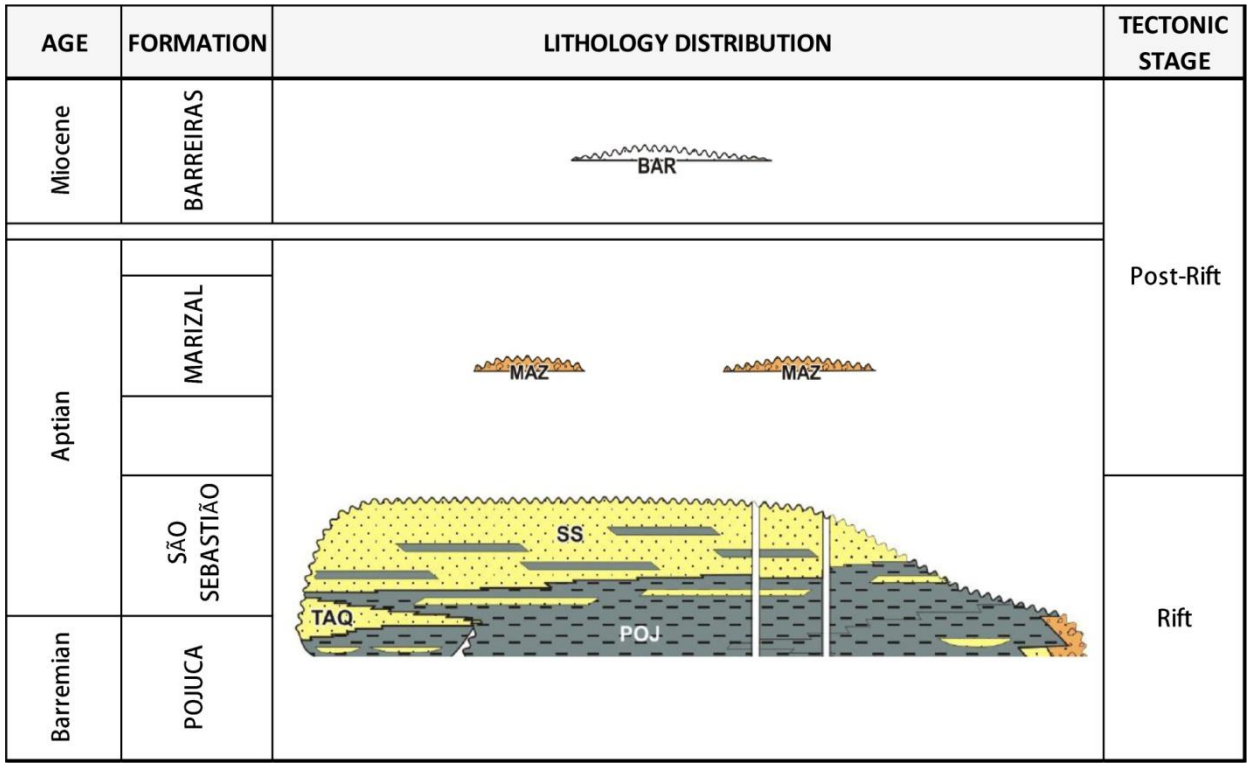

Figure 2. Upper interval of the stratigraphic column of Recôncavo Basin (adapted from Silva et al., 2007).

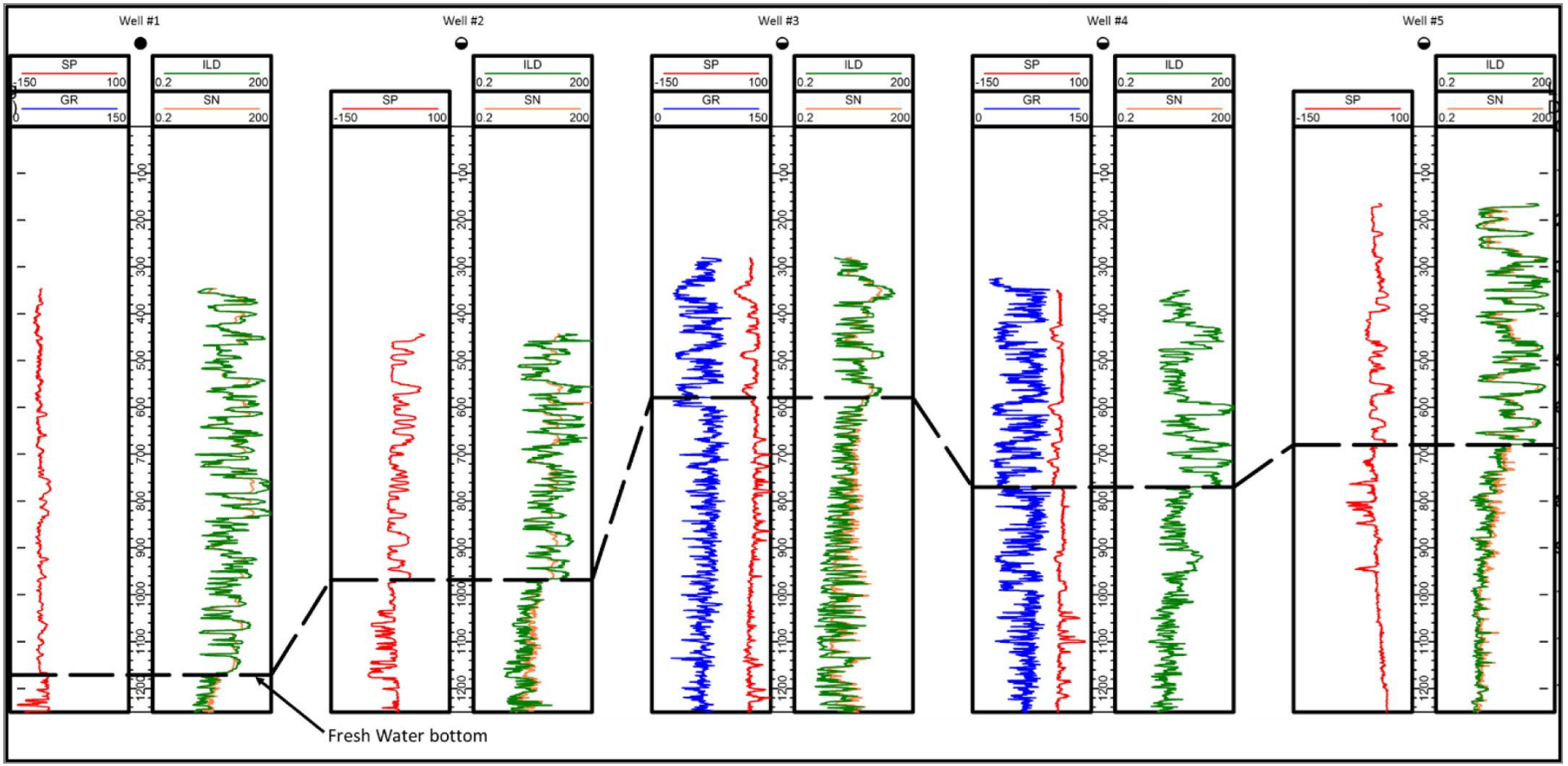

Figure 3. Well-log cross-section showing typical log signatures of the base of the fresh-water zone--at the abrupt decrease of the resistivity log curve, ILD and SN, displayed in green and orange color, respectively, on track 2. GR and/or SP displayed in blue and red color, respectively, on track 1. Note the significant decrease in the resistivity within the clean sands, shown in Well #4, as well as the decreasing resistivity baseline within the shales in all the wells. Also typical is the reversal of the SP deflection of the clean sands above and below the fresh- to salt-water transition evident in all of the cross-section wells.

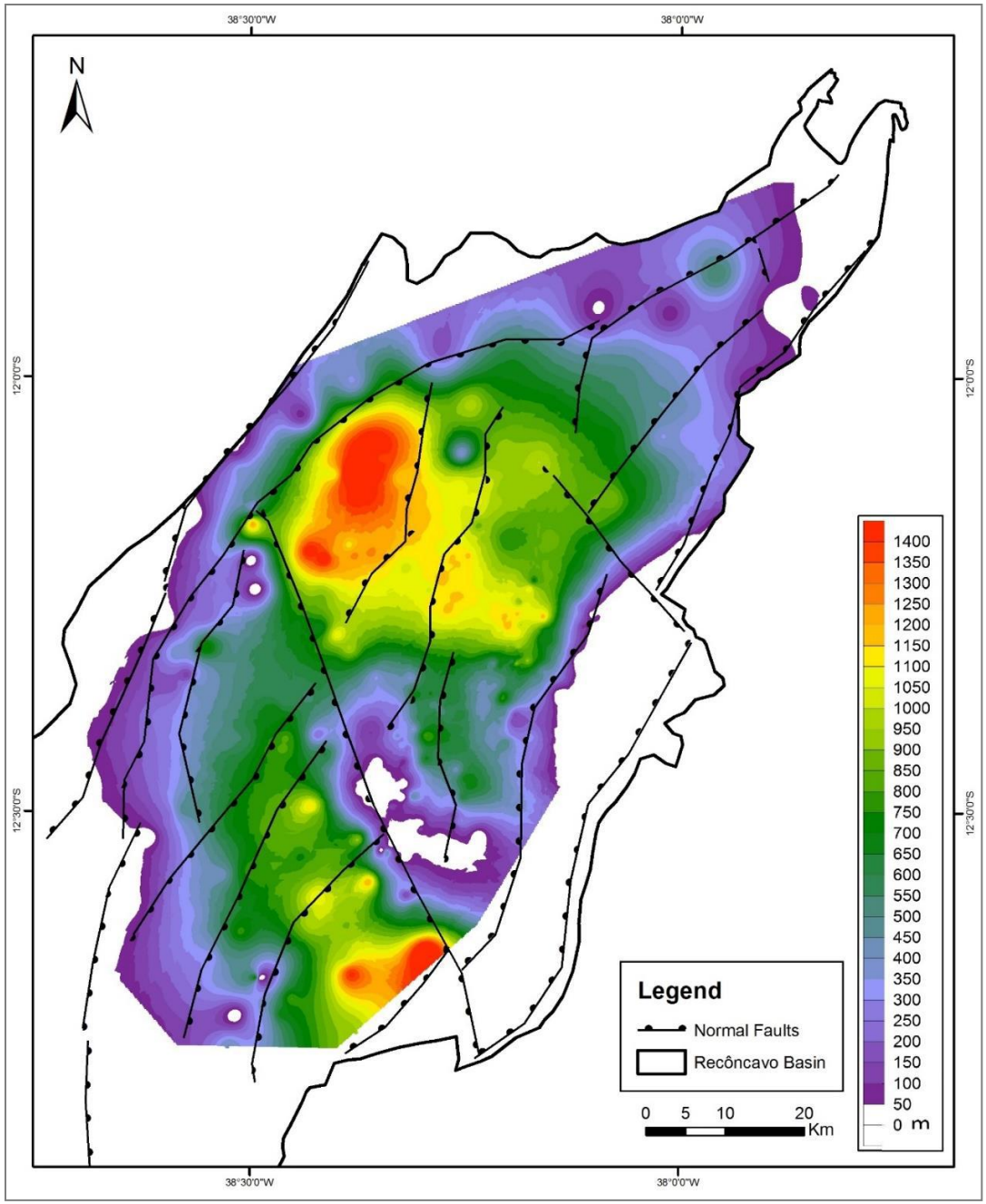

Figure 4. Ground-water aquifer isopach map from Recôncavo Basin.