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EA A Corporate Strategy for Reducing Dry Holes and Improving Resource and Reserve Estimates*

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Abstract

Reserve estimates, both before and after the bit, require accurate maps. Well post-mortem studies conducted for wells drilled in the North Sea and Gulf of Mexico over the last 30 years suggest that 50 to 65% of the dry holes drilled by industry failed as a result of trap or seal failure. Further review indicates that many of these dry holes were drilled on the basis of interpretations or structure maps that were not accurate and often geologically invalid. Since a significant percentage of dry holes were dry holes because they were drilled on bad maps, then adapting a strategy that ensures that the subsurface interpretations and maps are accurate can reduce the number of dry holes by 25 to 50%. We propose a three-part strategy that companies can employ to reduce dry holes and improve pre and post drill estimation of resources and reserves. This strategy will help companies make better decisions, reduce dry holes, and should help avoid the need to write-down reserves. 1) Training: A common management complaint is that many interpreters today do not understand their maps. Interpreters who do not understand their maps are very likely to make bad maps, and bad maps cause dry holes and result in incorrect estimates of reserves and resources. Companies need to provide their interpreters with the specific training they need to ensure that they can make high quality geologic interpretations and maps. Additionally, all geoscientists should be trained in the fundamentals of reserve and resource estimation and have familiarity with the Petroleum Resource Management System (PRMS). 2) Pre-drill reviews and audits: Before making a decision to drill a well, the interpretations and maps should be subjected to a pre-drill review process. The review should first ensure that all elements of the petroleum system have been defined for the prospect. Then the structure maps that are the basis for the well and the resource estimate should be subjected to a pre-drill audit, which is essentially the same as a well post-mortem, minus the cost of the dry hole. 3) Pre-well reviews: Whether the well is a success, or a failure, companies should conduct a post-well review. The review should examine what the well revealed about the petroleum system and whether the targets came in as predicted. This paper will define the strategy for reducing dry holes and improving resource and reserve estimates, and the pre and post well audit process will be discussed.

Introduction

We make decisions on whether or not to drill a well, or whether to acquire a field or prospect on the basis of our expectation of the value of the prospect of field, which we determine from structure and isochore maps of the subsurface. If the subsurface interpretations and maps that are the basis for our decisions are bad, then the decisions we make from them will also be bad.

I will assume that no manager wants to drill dry holes, and no investor wants to make bad investments. Yet many managers are aware that the maps generated by their teams are not accurate. They often try to mitigate that by increasing the trap risk. This, however, is a seriously flawed approach, since the decisions are still being made on bad maps. Bad maps = bad investments and dry holes; lots of dry holes!

Bad Maps Cause Dry Holes

Well post-mortems have indicated a wide range of reasons for why exploration wells have failed. These reasons include lack of reservoir, lack of charge, lack of seal, and lack of trap (Tearpock et al, 1994; Loizou, 2003; Tearpock, 2006; Mathieu, 2015; Rudolph and Goulding, 2017). This paper will examine the principal causes of dry holes and will present a strategy that companies can implement to reduce the number of dry holes they drill.

A review of 98 dry holes in the North Sea indicated that 55% of the dry holes were failures due to a lack of trap or seal (Figure 1A) with reservoir failure accounting for 28% of the dry holes and lack of charge for 14% of the dry holes (Mathieu, 2015). A twenty year lookback review of dry holes drilled by Exxon, Mobil, and ExxonMobil between 1994 and 2015 (Rudolph and Goulding, 2017) concluded that trap and seal failure accounted for 51% of the dry holes (Figure 1B), with failure of the petroleum system accounting for 27% of the dry holes and lack of reservoir, an element of the petroleum system, being the cause for 22% of the dry holes.

A similar lookback review conducted by Schlumberger looked at the drilling results of 20 companies and found that trap and seal failure accounted for 55% of the dry holes (Figure 1C), with reservoir failure accounting for 15% of the dry holes and lack of charge accounting for 30% of the dry holes (Karlo, personal communication). Post-mortem well reviews conducted by Subsurface Consultants & Associates, LLC have found that approximately 54% of the dry holes failed due to a lack of trap or seal (Figure 1D), and lack of reservoir accounted for 31% of the dry holes. Thirteen percent of the wells examined had noncommercial accumulations and 2.5% of the wells failed as a result of mechanical problems (Tearpock, 2006).

Based on these diverse post-mortem reviews, we can see that trap and seal failures account for slightly more than 50% of the industry's dry holes. Failure of one or more elements of the petroleum system, either charge or reservoir account for the remaining dry holes.

However, in his post-mortem reviews, Tearpock (2006) conducted a full audit of the maps using various quick look and quality control techniques to determine if the maps and interpretations were valid (Tearpock et al, 1994). Tearpock found that the majority of dry holes attributed to trap and seal failures were actually drilled on structure maps that were incorrect, and often portrayed structures that were geometrically impossible. In short, these wells were all but guaranteed to be dry holes before they were drilled.

Loizou (2003) examined a number of dry holes drilled along the UK Atlantic Margin, For those dry holes drilled on structural traps, approximately 65% of the wells lacked a sound trap configuration (Figure 2); a sound trap being defined as a robust structural closure or a combination structural stratigraphic feature that can be mapped with high confidence utilizing good quality seismic and other key data (Loizou, 2003).

Based on Tearpock's and Loizou's studies, we can see that almost half of the industry dry holes are the result of drilling prospects that were improperly mapped. This begs the question; just how bad are our maps?

Bad Maps = Bad Investments

There are, unfortunately, far too many examples of bad investment decisions based on bad maps to be included in this paper. We will discuss a few examples to help illustrate the severity of the problem.

One of the most common mistakes we see is fault aliasing or connecting two or more different faults as one. We can see that mistake in an example of a dry hole drilled in the Gulf of Mexico. If you look at the structure map shown in Figure 3A, you will observe a three-way closure against an east-west trending fault. The map was constructed from a tight grid of 2D seismic lines. With closer examination of the offsets along that fault we can see that the left side of the fault is down to the north whereas the right side of the fault is down to the south, a geometrically impossible interpretation in an extensional setting. The east-west trending fault is actually two individual faults (Figure 3B) separated by a relay ramp so there is no closure. This could easily been seen if the interpreters had constructed a fault surface map. So, for the lack of a fault surface map the investor's lost $5.5 million. This dry hole could also have been avoided if management had simply conducted a pre-well audit of the map.

Figure 4 illustrates another example of a multi-million-dollar loss as a result of the failure to make a fault surface map. In this case, the operating company is selling a producing field in the offshore Gulf of Mexico. Based on the seller's map (Figure 4A), constructed with 3D seismic and 12 wells, a company purchased the field. Once the new owner loaded the field data, their interpreters constructed a fault surface map and integrated it with the horizon. They observed that in their final maps, the closure is much larger than portrayed in the seller's maps (Figure 4B). The seller had incorrectly picked the fault though a fault shadow with the result that they had mapped a much smaller closure area than was present. This caused the purchasing company to get approximately 30 BCF of gas free of charge., whereas the selling company lost out on almost $30 million dollars.

In still another example of a bad map resulting in a bad investment, a company based their purchase price of a field on the net pay isochore map prepared by the seller (Figure 5A). However, we can see that the contours do not turn at the inner limit of water, so we know the isochore map is incorrect and over estimates the field's reserves. The reserves determined from the correct isochore map (Figure 5B) are 12% less than the reserves estimated from the incorrect map, resulting in a loss of $37.5 million dollars to the investors.

A Strategy to Reduce Dry Holes and Improve Investments

As we can see, bad maps result in bad drilling decisions and bad investments. Companies looking to increase their drilling success and investors looking to make wise investment decisions need a strategy to help them eliminate bad maps. We recommend a three-part strategy that incorporates 1) training and mentoring, 2) pre-well reviews, and 3) post-well reviews.

Training and Mentoring

A common management complaint is that many interpreters today do not understand their maps. Interpreters who do not understand their maps are very likely to make bad maps and as we have seen, bad maps cause dry holes and bad investments.

The collision of the price collapse with the industry crew change has left our geoscience workforce under-trained and under mentored, resulting in a large capability gap. This has been both helped by, and exasperated by, technology improvements. Technology improvements have helped the industry to maintain exploration success rates similar to those before the crew change. However, the reliance on technology to make interpretations and maps has resulted in many bad maps. This trust in the workstation has led to a loss of interpreting and mapping skills, and the vast majority of interpreters are not aware that the map generated in their workstation is wrong, sometimes very wrong (Figure 2, Figure 3, Figure 4, and Figure 5).

Interpreters must receive the training they need to make valid interpretations and maps of the subsurface. Training, particularly for early career professionals, needs to be focused on providing the interpreters the fundamental skills and expertise they need to make valid interpretations and maps of the subsurface. Training for mid and late career professionals should aim to reinforce those fundamental skills as well as to broaden their skills and subject matter expertise.

Many of the methods and techniques needed to make a valid interpretation and map are passed down from mentor to protégé’. As such, mentoring is as important as, and possibly more important than training. Younger staff need access to experienced individuals who can help them apply the methods and techniques needed to make valid interpretations and maps. As a result of the recent price downturn, many of the individuals experienced enough to be mentors have retired, so companies may need creative solutions to provide mentors to their staff. However, failure to do so will result in more bad drilling decisions and poor investments.

Pre-well Reviews

Before management or investors decide to drill a well, they need to review the interpretations and maps to make sure they are valid. The review should be conducted by management and mapping experts. Outside experts should be considered. They can provide an expertise beyond that found in the company, and they will be free of bias. It is worth noting that a pre-drill review costs the same as a post-well review, minus the cost of the dry hole.

The pre-well review should consist of a technical audit of the map and interpretation. The first step of the audit should be to ensure that all of the data was used and honored. Often maps coming out of the workstation do not honor all of the data since the gridding, contouring, and smoothing algorithms can result in the interpreter's picks being shifted. This can be seen in the depth structure map of a Gulf of Mexico gas field shown in Figure 6. The map was based on 3D seismic and 10 wells. Note that for all the wells highlighted by a blue arrow, the contours do not match the wells, with several contours off by more than 300 feet.

The structure map shown in Figure 7 is a perfect illustration of how a pre-well review or audit could have prevented two dry holes drilled in a field. The incorrect map that was used to justify drilling two wells to accelerate production was generated with 3D seismic and 15 wells. The map failed every step of the audit. Unfortunately, the audit was conducted as a post-mortem as opposed to a pre-well review. Had the company conducted a pre-well review, they would have been able to have the correct map to generate their drill locations, resulting in reserve additions to the field as opposed to two dry holes. For a review of the full audit process applied to the map the reader is referred to the SCA Webinar "*Would You Approve Drilling a Dry Hole?"* (Shoup, 2018) which is available on SCA's website (https://scacompanies.com).

Post-well Reviews

Once a well has been drilled, you should conduct a post-well review. In the event of a dry hole, you will want to determine what can be learned from the well to help eliminate any systematic bias and to improve the chance of success for the next well. If the well was a discovery, what is learned in the post-well review will help the appraisal and development process. The review should be conducted by the evaluation team and the results and conclusions presented to management.

Since it is not feasible to remap every structure after it has been drilled, there are several pre-drill and post-drill comparisons that are easy to make to confirm the structural validity. The first is the predicted depth versus the actual depth of the target horizon(s). As a rule-of-thumb, if the actual depth of the target varies by more than 10% of the predicted depth, remapping the horizon should be considered unless there is a corresponding difference in the pre-drill and post-drill time-to-depth conversion factor.

The second check for structural validity is to compare the dip of the target horizon with the dip indicated on the map. This will require running a dip meter or borehole image log. There is no rule-of-thumb for this check. Generally, if the strike varies from that shown in the well from that indicated on the map by 5% or more, the map should be re-contoured. Likewise, if the dip varies by 5 degrees or more, the map should be re-contoured

Summary and Conclusions

Almost half of the dry holes drilled by industry were dry holes because the well was drilled on a structure map that did not actually portray the subsurface structure. Although industry will never fully eliminate dry holes, companies can significantly reduce dry holes by employing a three-part strategy of training and mentoring, conducting pre-well reviews and map audits, and conducting post-well reviews or look backs.

1) Training

Companies need to provide their interpreters with the specific training they need to ensure that they can make high quality geologic interpretations and maps. Additionally, younger geoscientists need to have access to mentors in order to learn the methods and techniques they need to make valid interpretations and maps.

2) Pre-drill reviews and audits
Before making a decision to drill a well, the interpretations and maps should be subjected to a pre-drill review process. The review should first ensure that all elements of the petroleum system have been defined for the prospect. Then the structure maps that are the basis for the well and the pre-drill reserve estimate should be subjected to a pre-drill audit, which is essentially the same as a well post-mortem, minus the cost of the dry hole.

3) Post-well reviews
Whether the well is a success, or a failure, companies should conduct a post-well review. In addition to the review examining what the well revealed about the petroleum system it should also look at the pre-well predictions and post-well results in regard to the target depths and dip to help determine if the maps were correct or not.

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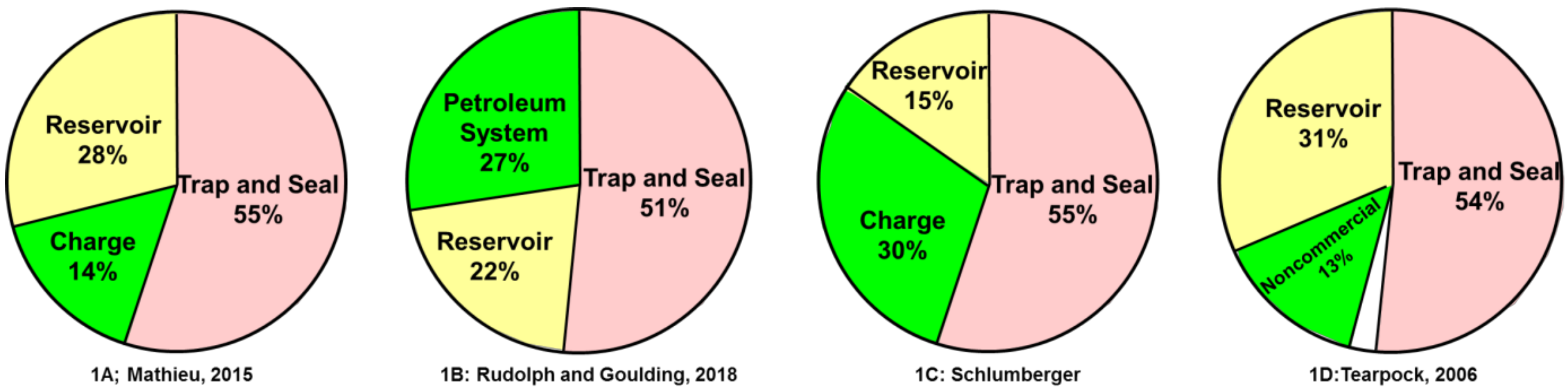

Figure 1. A) Dry hole analysis of North Sea wells show that 55% of the wells failed due to a lack of trap and/or seal (Mathieu, 2015). B) Twenty-year dry hole analysis of wells drilled by ExxonMobil indicates that 51% of the dry holes due to a lack of trap and/or seal (Rudolph and Goulding, 2017). C) Well review for 20 companies show trap and seal failures account for 55% of the dry holes (Schlumberger). D) Well post-mortem reviews conducted by Subsurface Consultants & Associates, LLC show that 54% of the wells failed due to a lack of trap and/or seal (Tearpock, 2006).

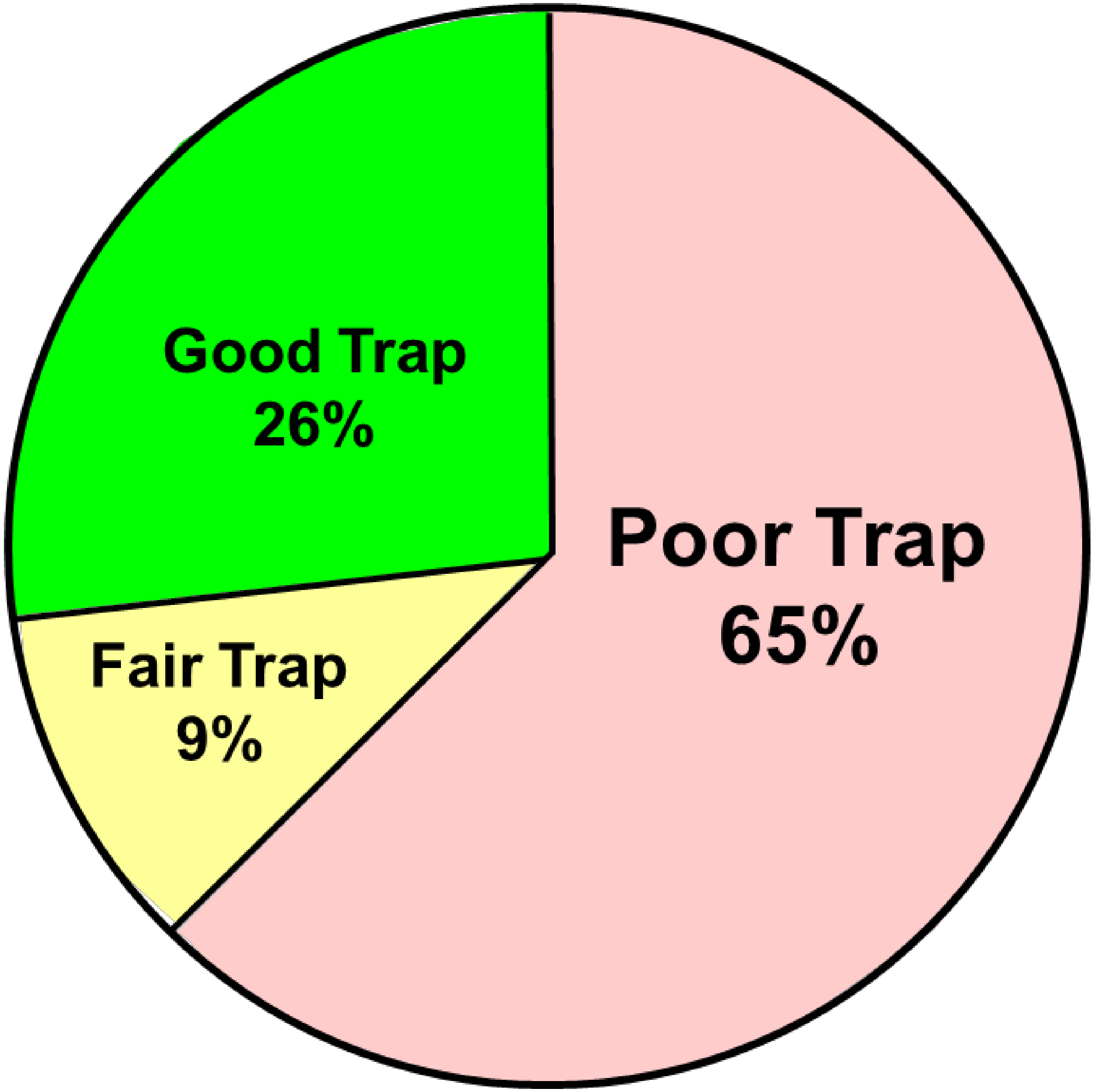

Figure 2. Dry hole analysis of wells drilled along the UK Atlantic Margin indicates that 65% of the dry holes drilled on structural traps lacked a sound trap configuration (Loizou, 2003).

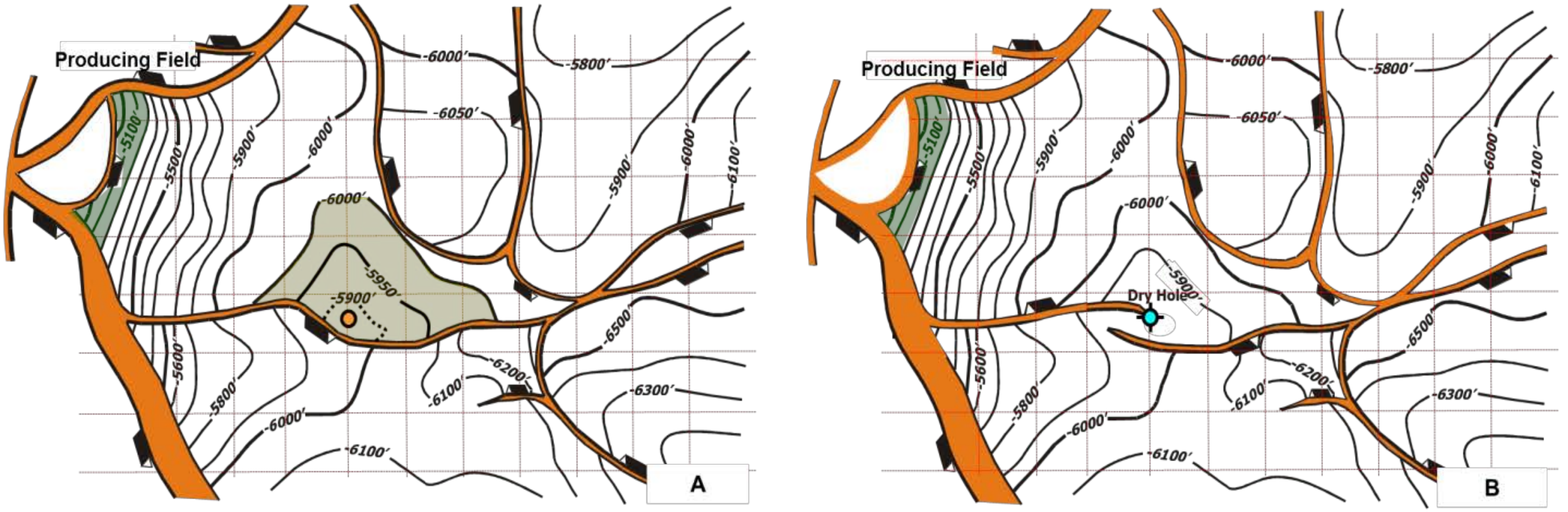

Figure 3. A) Pre-drill structure map portraying a three-way fault closure against an east-west trending fault. The map was constructed with a grid of 2D seismic (red dashed lines). B) Corrected map showing two separate faults and no closure. The two faults were aliased in the pre-drill interpretation. A pre-drill audit would have prevented this dry hole.

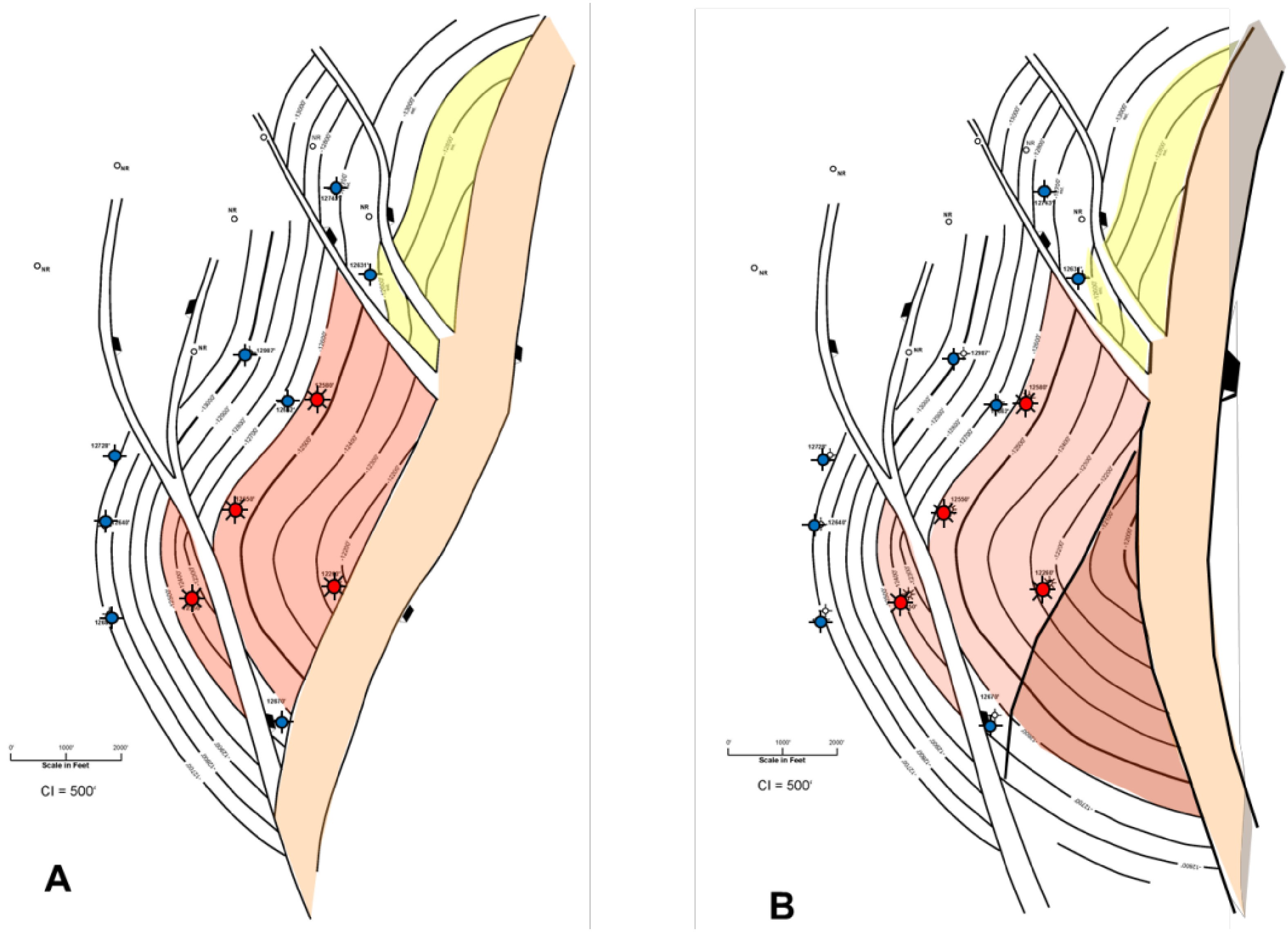

Figure 4. A) Seller's structure map of a producing field. B) Buyer's map after constructing a fault surface map and integrating it with the horizon, significantly increasing the closure area. The seller had incorrectly picked the fault in the southern portion of the field as a result of a fault shadow.

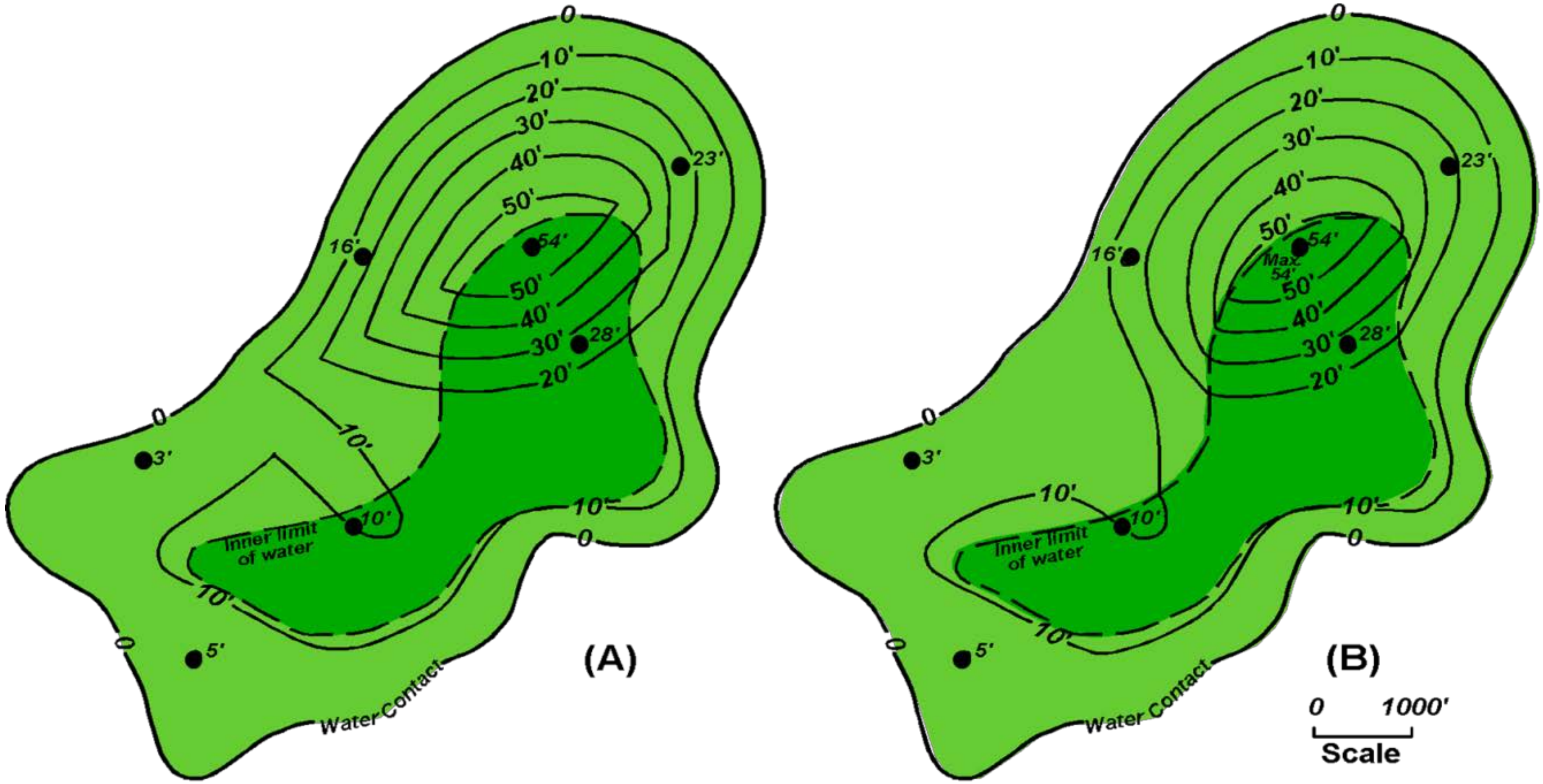

Figure 5. A) Seller's isochore map of a producing field. Based on the isochore map, the field is estimated to have 6.25 MMBO reserves. Volumes determined from the correct net pay isochore map B) are 5.5 MMBO.

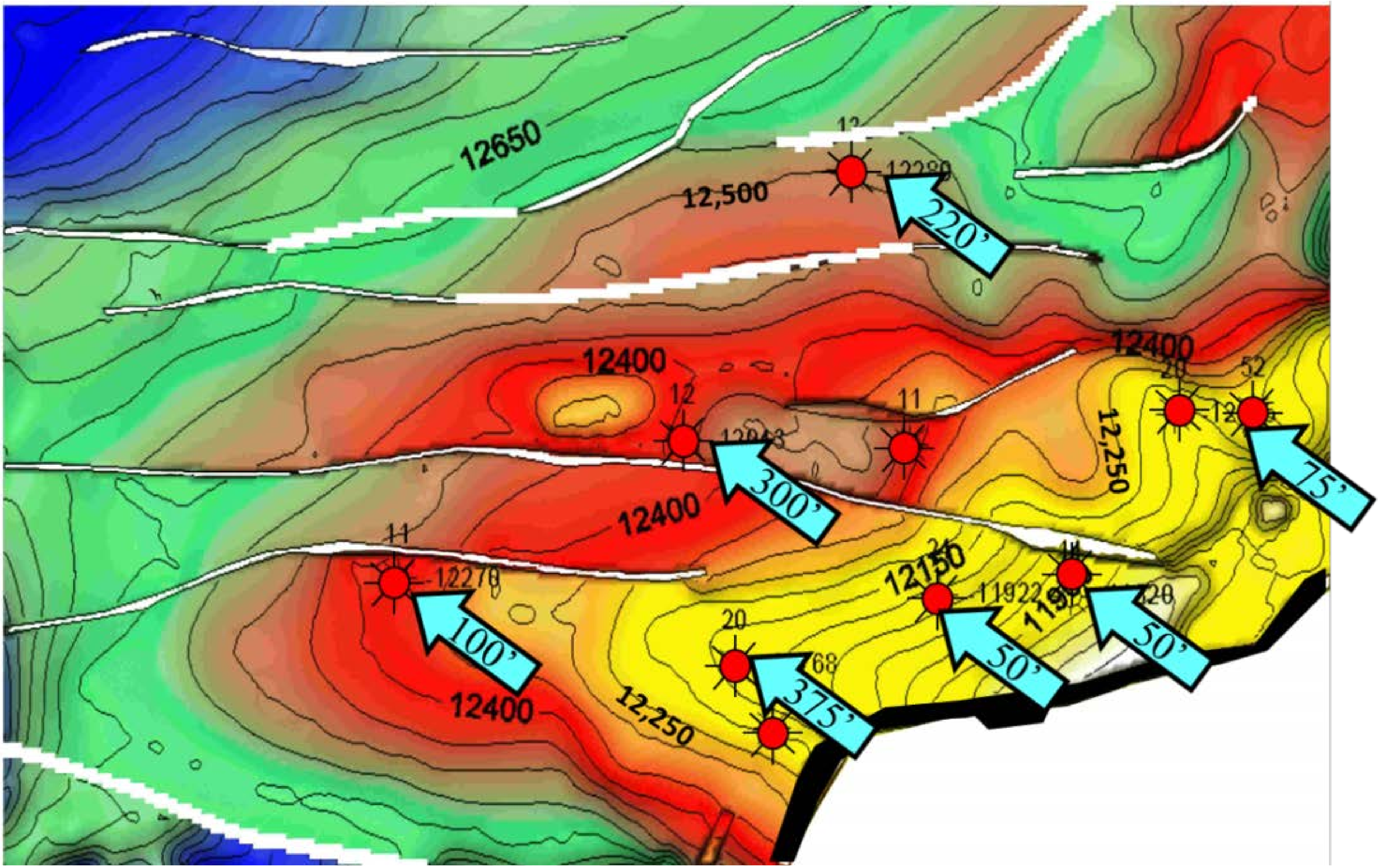

Figure 6. Depth structure map of a gas field in the Gulf of Mexico. Arrows highlight the wells where the contours do not match wells. The number in the arrow indicates the error between the well and the contour (in feet).

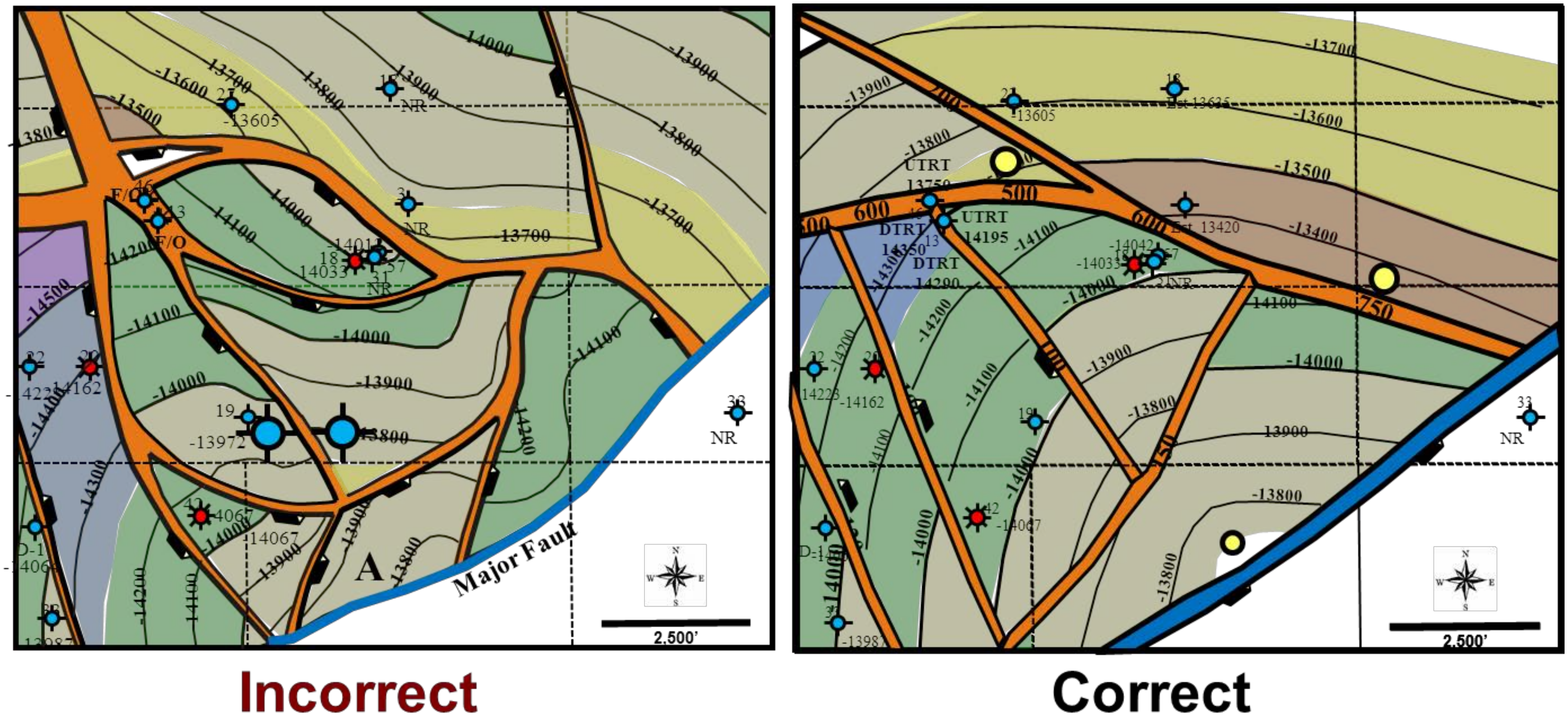

Figure 7. The incorrect map was used to justify drilling two wells to accelerate production in the field. The map was constructed from 3D seismic and 15 wells. In a post-mortem review after the wells were drilled, the map was found to fail every step of the audit process. Had the audit been conducted pre-drill, the map could have been corrected with the result of avoiding two dry holes and generating three good locations.