GIS Geospatial Data Quality and Mapping in Shale Plays – Technical and Business Impact*

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Abstract

This article discusses the technical and business impact of the management and quality of geospatial data in shale plays. Geospatial data are those data that define the coordinates of objects, their associated geo-referenced systems and their management during acquisition, processing and manipulation throughout the exploration and production (E&P) process (Figure 1). These data are used to prepare the maps that are used by industry decision makers when deciding where to explore for, drill, develop and produce hydrocarbons. Uniquely, geospatial data are critical to the efficiency of oil and gas exploration and production because no other component of the industry has the ubiquitous impact across all phases of the process.

Discussion addresses the impact of poor understanding of land boundaries, overestimating of reserves, overpayment of royalties and possible reduction of wells per unit, poor correlation of seismic and well data in interpretation, collision and fracture interference in the drilling of close proximity offset wells, possible loss of production through incomplete drainage of acreage, impact of directional survey errors on completions and fracturing placement and cost of poor design of facilities.

This article presents evidence that shows that the industry is about 65-70% efficient in its management of the quality of these positioning data, and that these data and the locations they describe are incorrect at a significant level the rest of the time. The financial implications are explored and some solutions are offered.

Introduction

The oil and gas industry is in a search for ‘buried treasure’. The ubiquitous component of any treasure hunt is the map used to find the treasure. Whether in R.L. Stevenson’s ‘Treasure Island’, Campbell Black’s ‘Raiders of the Lost Ark’ or Poe’s ‘The Gold Bug’, obtaining (sometimes nefariously) and interpreting the map properly are an essential foundation of the hunt!

In the oil and gas industry, some 80% or more of all (including business) data are spatially referenced. Geoscience and engineering data are close to 100% so referenced. Most oil company upstream companies are organized in vertical functions that include land acquisition (leasing properties and concessions), seismic acquisition and processing, data import and interpretation, drilling and directional drilling, reservoir development, completions and exploitation, facilities planning and installation and production (Figure 1). For any given asset, this organizational model is actually a 'data production line' that can take anywhere from 3 to 10 years to provide a return. This production line involves the combining of large number of heterogeneous digital datasets together to develop the product that at core, is a map of the potential prospects and leads to operational decisions (Figure 2). Such decisions include the interpretation and drilling location decision(s), directional and horizontal well survey planning and measurement, the completions methodology and efficiency, the calculation of reserves, the lease area and agreement on royalty payments and achieving expected ultimate recovery (EUR). Throughout this process, people, computer programs and data stores of one type or another are key 'players' in the management and manipulation of these data.

There are a large variety of heterogeneous data types, data sources, people who handle them, applications used to analyze and interpret them and managers and supervisors who have to make decisions respecting them. Successfully combining these data together in various combinations relies entirely on the integrity and proper correlation of their respective coordinates and reference systems. These coordinates are the glue that allows this process. This article describes these references and why it is that improper management of them, at each stage of E&P, can have such destructive impact on companies' revenue and profits, personnel and operational efficiencies. Some selected spatial references are listed in Table 1.

Figure 3 shows a diagram explaining the relationship between the geoid and three datums. Note that the geoid is not a surface that submits easily to computation, so geodesists have defined an ellipsoid that closely matches the geoid in the area that needs surveying. Once an ellipsoid (coordinate system that allows for a graticule of geographic, or latitude and longitude coordinates) is attached to the earth, the resulting object is described as a geodetic datum. Since latitude and longitude are referenced to the center of an ellipsoid, it is clear from the diagram that, by definition for the same physical point, a latitude and longitude coordinate on the green datum must be a different latitude and longitude on the red datum. Failure to properly identify the datum will lead to wrong juxtaposition or spatial relationship of elements on a map. Nowadays, many field surveys are conducted using GPS, which uses a global datum called WGS84. This would be represented by the blue ellipsoid in the diagram. Since most of our data in the US is referenced to North American datum of 1927 (represented in the diagram by one of the regional datums (green and red), then a failure to transform the coordinates before mapping the data will result in incorrect relationship on the map. Since projection coordinates (eastings and northings) are derived from geographical coordinates, they will be miss-plotted on the map unless the datum for the data is transformed from the field survey to the mapped datum. Figure 4 shows the impact of ignoring or confusing the datum on coordinates in West Texas and Montana. This can happen whenever the data are brought out from a database or project and combined with other data. Readers should also be aware that a height of a point measured by GPS is referenced to the ellipsoid and not MSL (~geoid surface) (Figure 5). This varies from -40 to +10 meters in the CONUS.

Figure 6 shows the principle of convergence angle, which is the angle between true north and grid north. This angle is of great importance in drilling and mapping the position of deviated wellbores. The diagram shows how the convergence angle correction needs to be applied depending on where in a projection the project lies in relation to the central meridian and the equator. A mistake of 1° in azimuth will result in a 20 ft per 1,000 ft of offset rotation in the wellbore. So the bottom hole location will be misplaced by 160 ft in an 8,000 ft offset well.

Grid azimuth = True azimuth – convergence angle. The sign of the convergence correction is critical. When west of the central meridian in the northern hemisphere the convergence angle is negative, so for example a True azimuth of 60°, and a convergence angle of -1° will be a grid azimuth of 61° thus Grid azimuth = 60° – (-1°) = 61°. East of the central meridian for the same true azimuth of 60° and a convergence angle of +1° this time, Grid azimuth = 60° - (+1°) = 59°.

Error Studies

Table 2 shows the percentage of seismic, well and boundary data found to be in error by significant amounts due to miss-manipulation and loading of data in G&G applications and company databases. Users cause some of the mistakes; some are caused by poorly designed applications. In both cases the primary cause is lack of knowledge about coordinate systems among both users and developers. Studies are both domestic and international.

Seismic, well and boundary data are the three types of data that have the most profound and direct impact on exploration and exploitation decisions. There are three components of these data types that are critical. The first is the specific content or primary data. In the case of seismic data it is the seismic reflective or refractive response of the earth to the seismic method. In the case of well data it is any of the many types of logged data and in the case of boundaries it is the legal agreement. The other two components are common and they are identity and location. The importance of these two components to the success of a given play and specific prospects within a play cannot be over-emphasized. They are not just two of many attributes but *sine qua non* 'super attributes'. All critical decisions will be based on mapped analysis of both the technical and the economic potential. Such maps are entirely dependent for their accuracy and their consequent value, on the integrity of the coordinates used to describe the juxtaposition of the data. This should therefore be assigned a greater importance than being simply one of many attributes of the data. This means that the entire success of a project could be jeopardized if the coordinates of only one set of data are mislocated, irrespective of the integrity and value of all the other attributes. The misplacement percentages shown are conservative. The author estimates that the average overall in these three categories of data is likely to be of the order of 30% or higher. The initial misplacement reported is more often a misrepresentation in a database than it is an actual misplacement on the ground, but the consequences can lead to misplacement of future operations in the field.

The studies represent a relatively small, but significant sample. In respect of these numbers, the well data misplacement is often caused by the lack of quality in the coordinates and the spatial metadata provided by the vendors of these data.

Case Histories

Land Leasing and Boundaries

Boundary surveys, locations and mapping have a very significant impact on all oil and gas operations. Determination of surface and mineral rights, acreage calculations and royalty awards, surface well location mapping and subsurface contouring, trespass, and reserve calculations within a lease or unit, are dependent on properly understanding, surveying and mapping of property boundaries. The status of many States boundary databases and courthouse records is very poor.

Figure 7 shows two boundary datasets in Texas that disagree by as much as 500 feet. Approximately 30% of the boundaries are affected. Any object surveyed and reported on a plat that references the incorrect boundaries will be misplaced on the map. Note that the boundaries on the ground are well known by local surveyors. The problem is the representation of those boundaries in digital files supplied by vendors or state agencies, and projected onto computer screen maps by geological, drilling and engineering staff from company databases. Figure 8 shows how wells are misplaced because they were mapped in relation to these boundaries; errors in mapping reach 500 ft in a predominantly north-south direction at the lower right part of the unit and 380 ft in a predominantly east-west direction at the top of the unit. So the mapping error is not systematic in size or direction. This is because the unit boundary misplacement on the map is different depending on the part of the unit. The wells are shown in their incorrect location and then connected by a blue line to the true location, derived by GPS re-survey. All the resurveyed well locations fall within the 'well pad' shown, except where the image predates the building of the pad. Note that the survey plats drawn by the field surveyors show the correct distances to the correct boundaries. It is the boundaries on the map that are misplaced. Also note that if the well locations are corrected and the boundaries are not, it can make it seem that a well is in the wrong unit. This would be true of the well in the bottom right-hand corner of the unit. The red line, if it is left uncorrected (to the yellow line location), looks like the boundary and therefore that well will look as if it is now in the other unit.

Figure 9 shows how acreage calculations can be impacted by incorrect boundary locations. This happens because the metes and bounds measurements in the courthouse ownership files do not fit the incorrect boundaries, so land GIS staffs 'rubber sheet' the measurements to fit them. In this case, excess royalties of approximately 8% will be paid.

Figure 10 shows a case where incorrect boundaries twice caused misplaced mapping of wells. This resulted in incorrect contouring of the subsurface. The diagram shows the corrected contours, which allowed commerciality of the prospect, and subsequent successful drilling of two new wells. The yellow wells were mapped to the yellow lease line (incorrect) and the blue wells were mapped to the blue lease line (incorrect). Both sets of wells were misplaced by about 500 ft. The original contouring failed to reveal the anticline and the fault closure. Once corrected, the prospects clarified and the two green wells were very successful gas producers. This result came about because of the persistence of the geologist who eventually went to the field and realized the boundary (which was also a road) had been incorrectly mapped. Without this zealous and time-consuming forensic approach, these two new (green) wells would not have been drilled.

Figure 11 shows a dependent re-survey of a township in Wyoming. Often, data from a USGS map will be digitized and the assumption is that the sections are regularly spaced and corners can be interpolated across a township or a series of sections. Such assumptions are very dangerous, as this case shows, and can lead to several hundred feet of error in mapped locations.

Surface Well Locations

Well surface locations can be surveyed or purchased from vendors. These locations are used for two primary purposes: (1) to provide a starting point for a wellbore, and (2) to provide an initial basis for contouring and mapping of the subsurface geology. In both cases, it is important to remember that inaccuracy will become misleading in a number of contexts, including the location of the target(s) derived from interpretation, the estimates of reserves, the possibility of collision between nearby wells and other subsurface structures and obstacles (e.g. shallow gas and faults) and reservoir analysis, planning and ultimate recovery of gas and liquids.

Figure 12 shows how a planned well, based on false boundaries, can end up misplaced. In this case, the 3D survey is correctly positioned and mapped. The ‘calls’ to the boundary line of a proposed well are measured on the screen and sent to the surveyor. The surveyor correctly identifies the relevant mineral lease boundaries on the ground and uses the provided measurements to stake the well. Because the ground truth boundaries are different to those on the computer screen (from the company database), the well will end up misplaced with respect to the 3D survey. What has happened here in reference terms is that the database boundaries essentially moved the local reference – the boundary corner.

Figure 13 shows an example of how contouring can be affected by incorrect mapping of the surface location of wells in a multi-well field. The left hand map was developed from the Texas Railroad Commission (TRRC) well database. The right hand map was developed subsequent to a GPS re-survey of all the wells in the field. There is a significant difference in the interpretative contouring and in the subsequent field development plan and anticipated reserves estimates and recovery.

Figure 14 shows an example of some data provided by a vendor showing 6 wells both with surface and subsurface locations. Three of the wells are not connected between surface and bottom hole locations. While this may not present a huge problem to resolve, doing so with an upload of several hundred or even thousands of wells would present unacceptable delays and probably create more errors. From the studies shown above, any geoscientist can expect that 1 in 3, to 1 in 4 wells are misplaced by over 100 ft when taken from a vendor or company database, so this presents a significant challenge to those whose role is to determine where to drill and what to expect in terms of reserves, obstacles and potential collisions.

Wellbore Surveys

The first wellbore position case (Figure 15) is one where the location of the well is very close to a projection boundary change. It is in Texas North Central State Plane Projection zone but very close to the boundary with the Texas Central State Plane Projection zone and the field overlaps the two projection zones. There are several wells on both sides of the boundary and a 3D survey that also overlaps the boundary. The difference in convergence between Texas Central and Texas North Central zones is (2.18-0.76) which is 1.42°. So for every 1,000 ft of offset, the well bottom-hole location will be miss-plotted by a rotated 28 ft. If the project is mapped in UTM, then the rotation is 3.18° (1.53-{-1.65}), and the offset is 64 ft rotation per 1,000 ft.

Figure 16 shows a cross section view of what are reported to be straight wells in West Texas. The five geologists in this play reported that they spent 80% of their time trying to rectify the location of the wells and 20% developing the field. Staff time wastage can be a significant cost. If the two numbers are reversed it represents a 300% improvement in staff time efficiency.

Figure 17 shows an elevation diagram for wellbore surveying. Correctly managing the elevation on the surface and depth below the surface is often more difficult than it seems. Problems that can occur are misunderstanding whether a reported height is referenced to MSL or to the ellipsoid as mentioned above (Figure 5). Other issues are whether the pad surface elevation is before or after construction of the pad. Is True Vertical Depth (TVD) measured relative to MSL or to Ground level? Measured Depth may be miscalculated due to wrong drill pipe count. Inclination error affects both along hole and TVD. A significant issue is that often more than one rig is used to drill one well. In many cases there are multiple leases or units and the operational plan is to drill one well in each unit in order to hold the unit by production (HBP). In some cases there are 2 rigs – one to drill the vertical section and one for the horizontal section, so there are two Kelly Bushing (KB) elevations, which need to be carefully recorded. Later after drilling only one well in each unit, additional rigs are used to execute the infill drilling in each unit. These may again be different rigs and there are additional KB elevations. Who is minding the recording and distribution of these data to ensure that later operations that are dependent on these data are being applied correctly?

Completions and Production

Figure 18 and Figure 19 show two possible problems with impact wellbore positioning on operations and production. The pictures are stylized showing five wellbores with one wellbore location rotated due to a convergence or magnetic declination correction. In Figure 18 this would result in lost production due to the gap between the frac zones, and in Figure 19 this would result in interference between the frac zones and loss of production.

Figure 20 shows a seismic data inversion in which 45% of the wells were at least 250 meters misplaced. An inversion creates a wavelet model for producing wells to allow additional prospects in the play to be identified. If the wavelet model is distorted because of miss-positioning of nearly half the wells, the model will not provide the match that is really needed.

Figure 21 shows the completions plan using regularly spaced stages for perforating and hydraulic fracturing. Acknowledgement of the source of this idea comes from SPE article 138427. This article argues for the use of LWD, where commerciality validates such a decision, in addition to geo-steering and gamma ray surveys in order to allow targeting of high production shales versus low production shale sub layers and to keep more closely within the layers. This additional information identifies where the most productive zones are through additional information about rock properties and mineralogy. The inclusion of this diagram here is to point out that highly accurate positioning of the wellbore is essential in order to be able to place the perforations and frac zones exactly as indicated by the LWD. Given that 1 in 4 wells and wellbores are misplaced on the maps as shown earlier and there are numerous other ways in which the wellbore data can be miss-mapped, the assumption that the quality of positioning is good enough to do this is one that should be questioned.

Discussion and Analysis of Financial Implications

Table 3 shows the statistical impact on operations, based on a generic Six-Sigma analysis, between the 'defect' percentage and the percentage of resources wasted. This dataset was obtained from the manufacturing industry model for assessment of the cost of defective products on a production line. E&P workflows are using data in much the same way – as various types of data move through and are combined in the E&P workflows in various functions.

Table 4 shows the actual impact of the studies with respect to each type of data, by applying the Table 3 standard. Validity of this model approach should rightly be questioned. Today's E&P cycle is a production line, in which various data types are combined into product(s): the maps used to make multiple important and expensive decisions, throughout the cycle. The fact remains that almost 100% of these data have a coordinate or some method of determining position that is the 'glue' that allows the various heterogeneous datasets to be combined. If the spatial component of these data is flawed at a level outside an acceptable tolerance, then the resulting maps and the decisions associated with them can have significant operational and financial consequences.

From Table 4 then, the estimated wastage of budget resources is an average of 37%, which includes:

- Lost staff time
- Operational inefficiencies in drilling operations, poor completions and recovery implementation
- Misplaced wells
- Wrong decision not to drill

There are multiple causes of these geospatial issues:

- Functional versus asset based performance
- Separation of field from office and digital data management
- Lack of (1) training, (2) metadata discipline, (3) attention to geospatial metadata, (3) supplier contract specifications and supporting deliverables
- Mistyping
- Multiple instances of a given well or boundary due to varied computational handling by different asset staff
- The idea that one quality or accuracy criteria is acceptable at all stages of E&P
- Desire for automation at the expense of accuracy
- Lack of authorized senior management oversight

Some Improvement Possibilities

Some systematic changes must be made to address the issues outlined. A full solution must address the issues in multiple ways:

- Functional operations planning and evaluation
- Operational and historical data review
- Industry collaboration on updated and new standards and specifications, data models and formats

Underlying these strands are geospatial quality, and management of vision, mission and goals policy on which are based procedures and existing standards and specifications. The three strands provide a feedback mechanism for a corrective action methodology and input to a structured training program, which should be ongoing for all asset personnel. This plan would allow incorporation of specific checkpoints into the business workflows and supporting operational planning through representation in asset teams.

Conclusion

Implementation of the described procedures and organizational issues discussed in this article will bring discipline to a company's management of geospatial data, the personnel involved and the applications they use. If nearly 40% of the budget were being wasted – then at a 15% return that would increase overall return by 60%. The current organizational structure and motivational culture of oil and gas companies works against and prevents the concepts and ideas in this article from being implemented. Companies are paying an unseen price, in lost efficiency and profits, for this oversight. The scale of this loss is significantly greater than most corporate leaders are willing to admit. This situation closely mirrors, conceptually, the health and safety losses that preceded the rise of company HSE protocols in the 1980's and 1990's with the difference that this challenge is essentially invisible because of the technological revolution in digital data and software applications. The management of these spatial data and the associated applications are essentially misdirected and out of control with respect to spatial data. This situation represents a significant unmitigated risk to the ongoing health of the industry for both companies and their shareholders, their employees and their suppliers, as well as the governments and peoples that depend on these hydrocarbon resources and associated tax revenues.

The result of well-implemented changes in the management and quality of geospatial data will bring about:

- Enhanced E&P opportunities
- Mitigation of portfolio risks
- Safer operations
- Improvement in staff job satisfaction
- Improved and faster reserve replacement
- Better estimation of reserves
- Higher return on investment
- Increase revenue and profit
- Higher reliability of supply

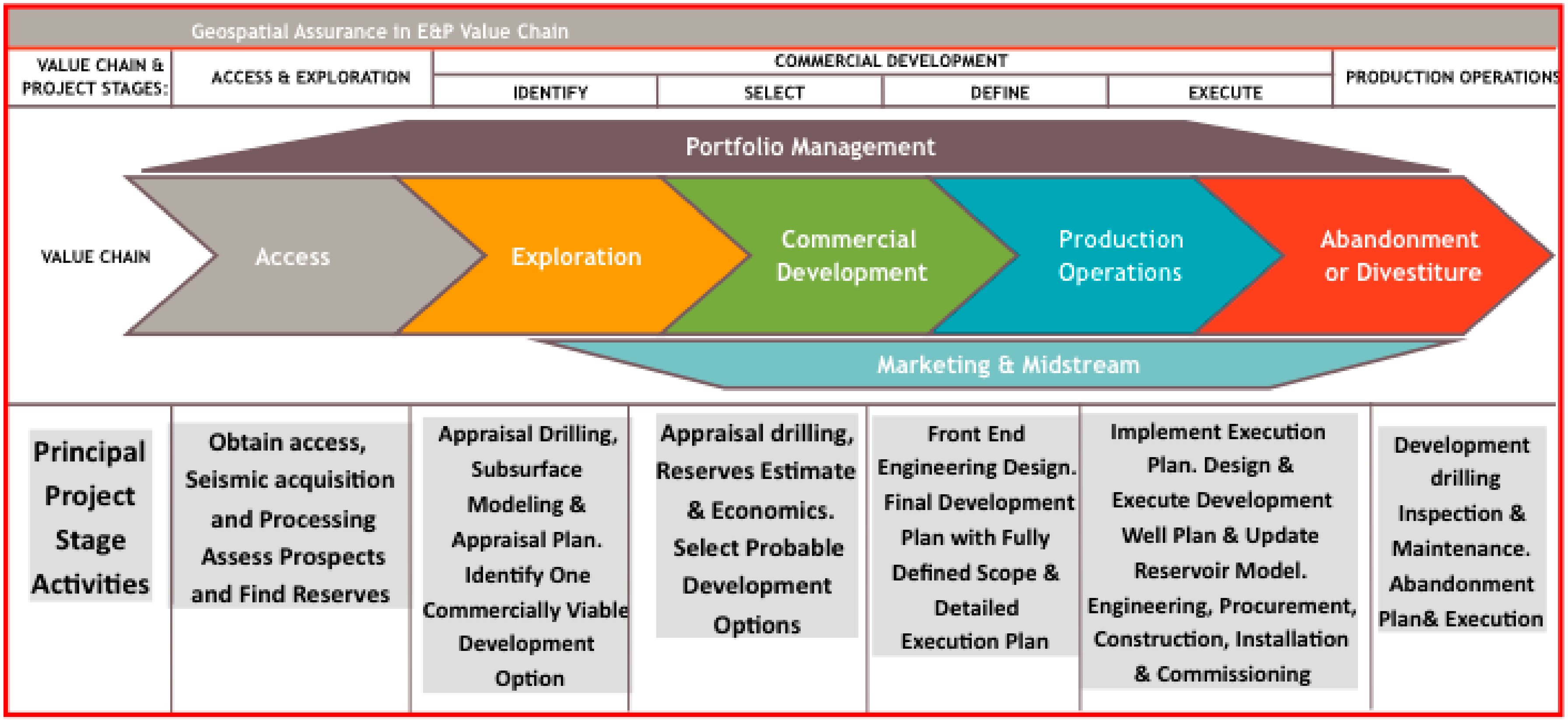


Figure 1. Exploration and Production workflow showing some key geospatially dependent activities at each.

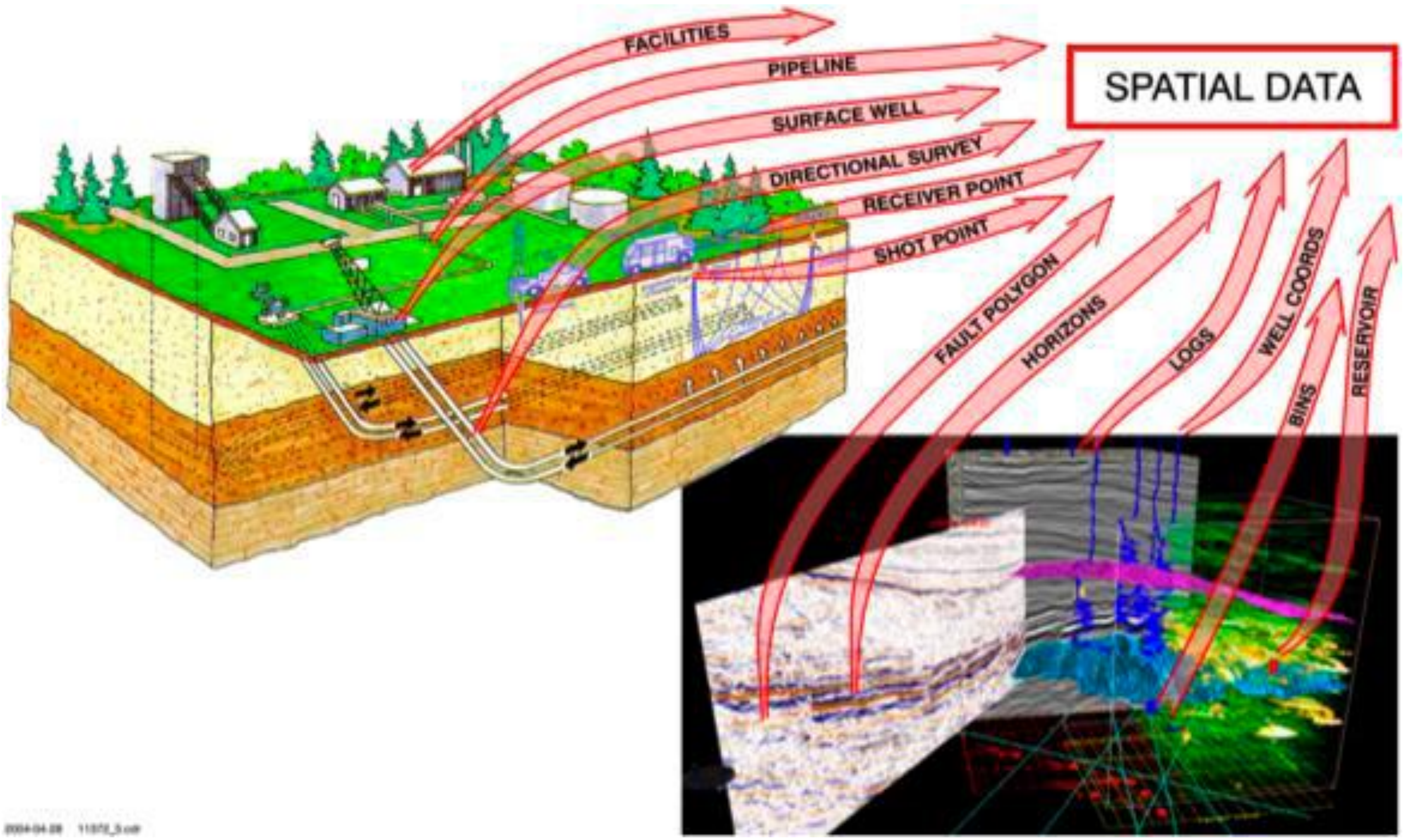


Figure 2. Diagram demonstrating the variety for data types being combined in E&P.

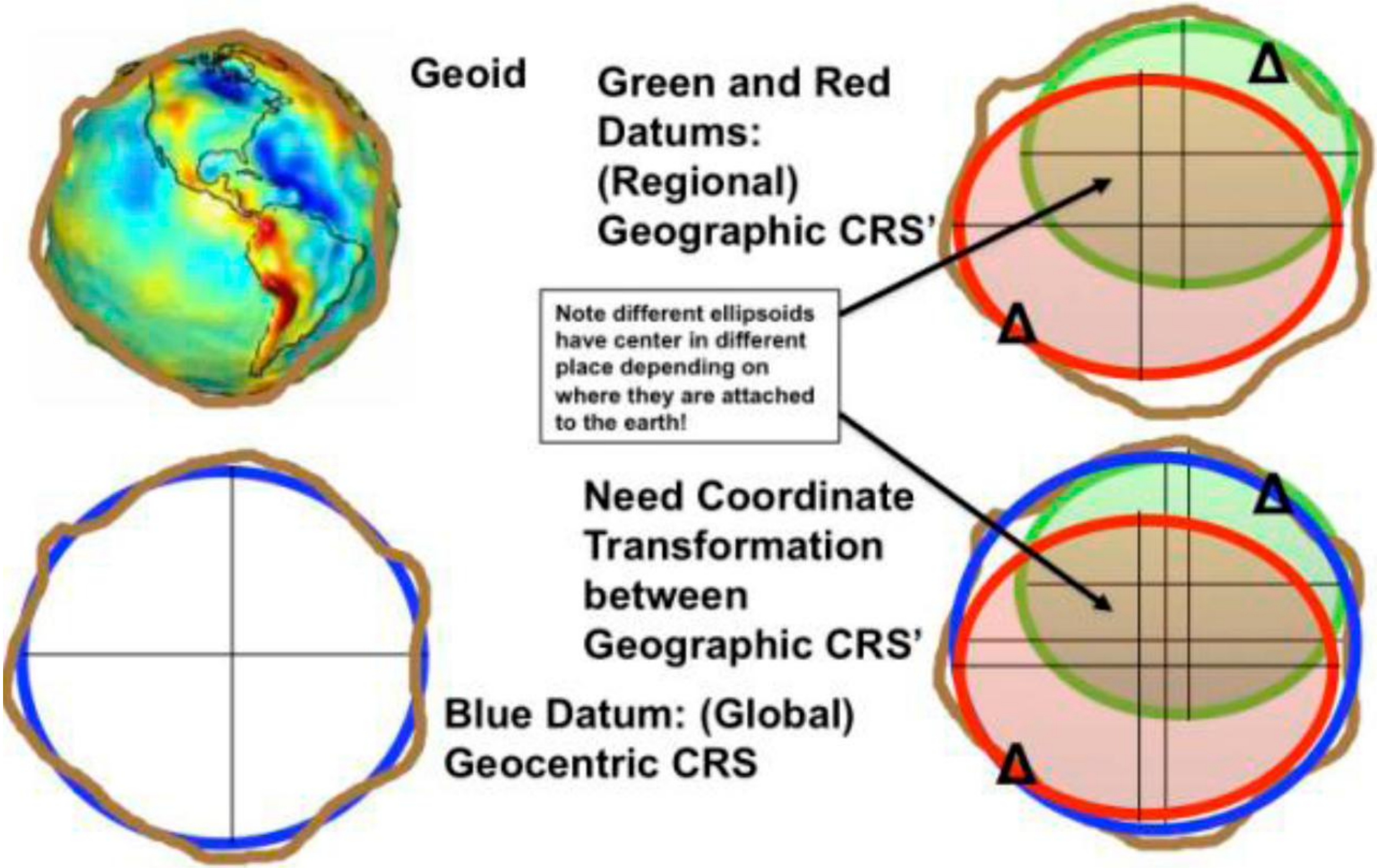


Figure 3. The Geoid (irregular) outline, two regional datums (green and red) and a global datum (e.g. WGS84) in blue.

- West Texas
  Texas Central Zone
- NAD27
  - Lat: 32° N
  - Long: 105° W
- NAD83
  - 32° 00' 00.54" N
  - 105° 00' 01.87" W
- Differences
  - DE 158.8 ft (ftUS)
  - DN 60.9 ft (ftUS)
  - DR 170.0 ft (ftUS)

- Montana
  Montana South Zone
- NAD27
  - Lat: 45° N
  - Long: 112° W
- NAD83
  - 44° 59' 59.654" N
  - 112° 00' 03.075" W
- Differences
  - DE 222.0 ft (ftUS)
  - DN 30.0 ft (ftUS)
  - DR 223.7 ft (ftUS)

Figure 4. The amount of error in mapping of data in West Texas and Montana if the datum between NAD83 and NAD27 are confused.

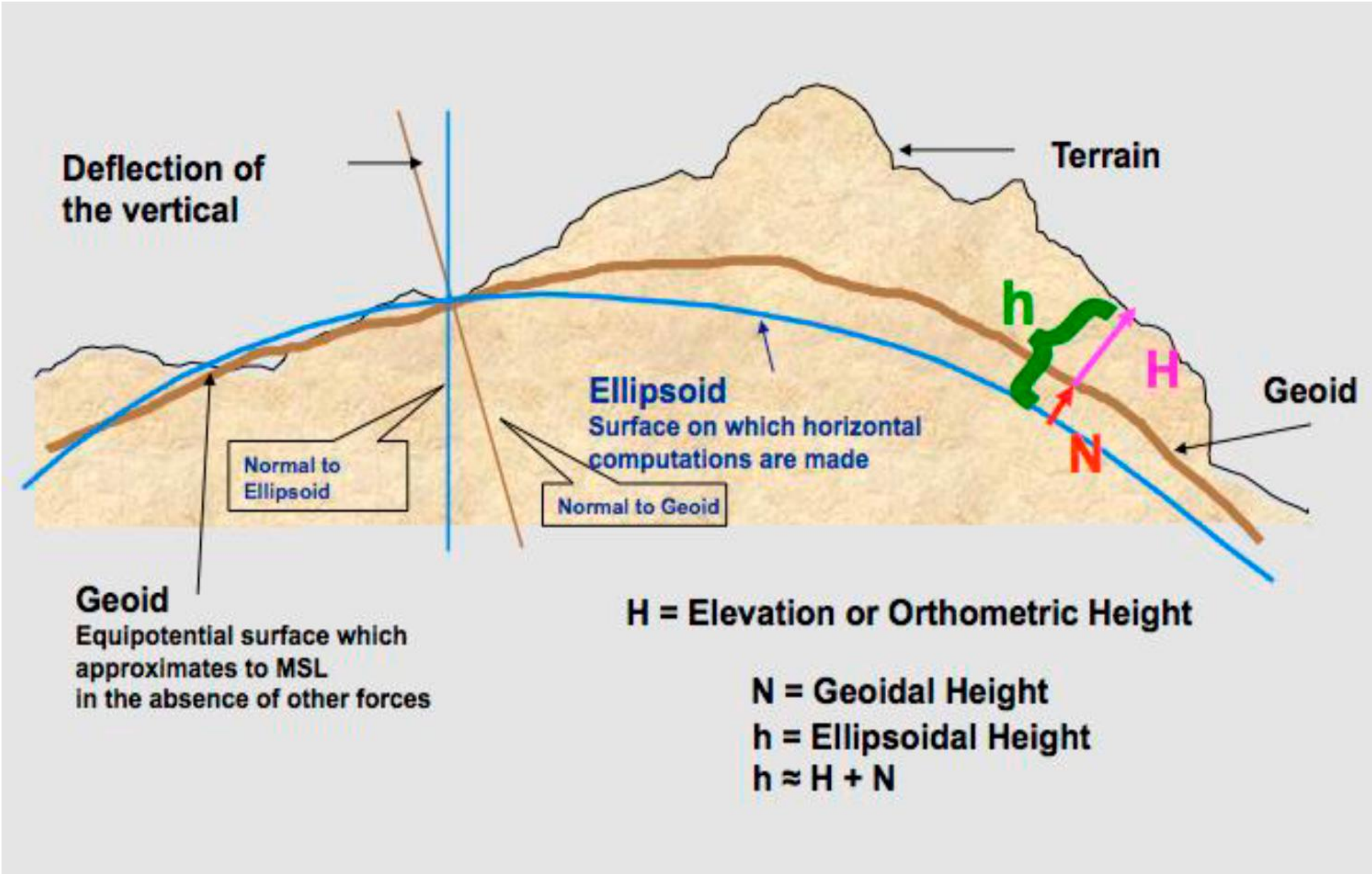


Figure 5. The vertical relationship between Ellipsoid and Geoid.

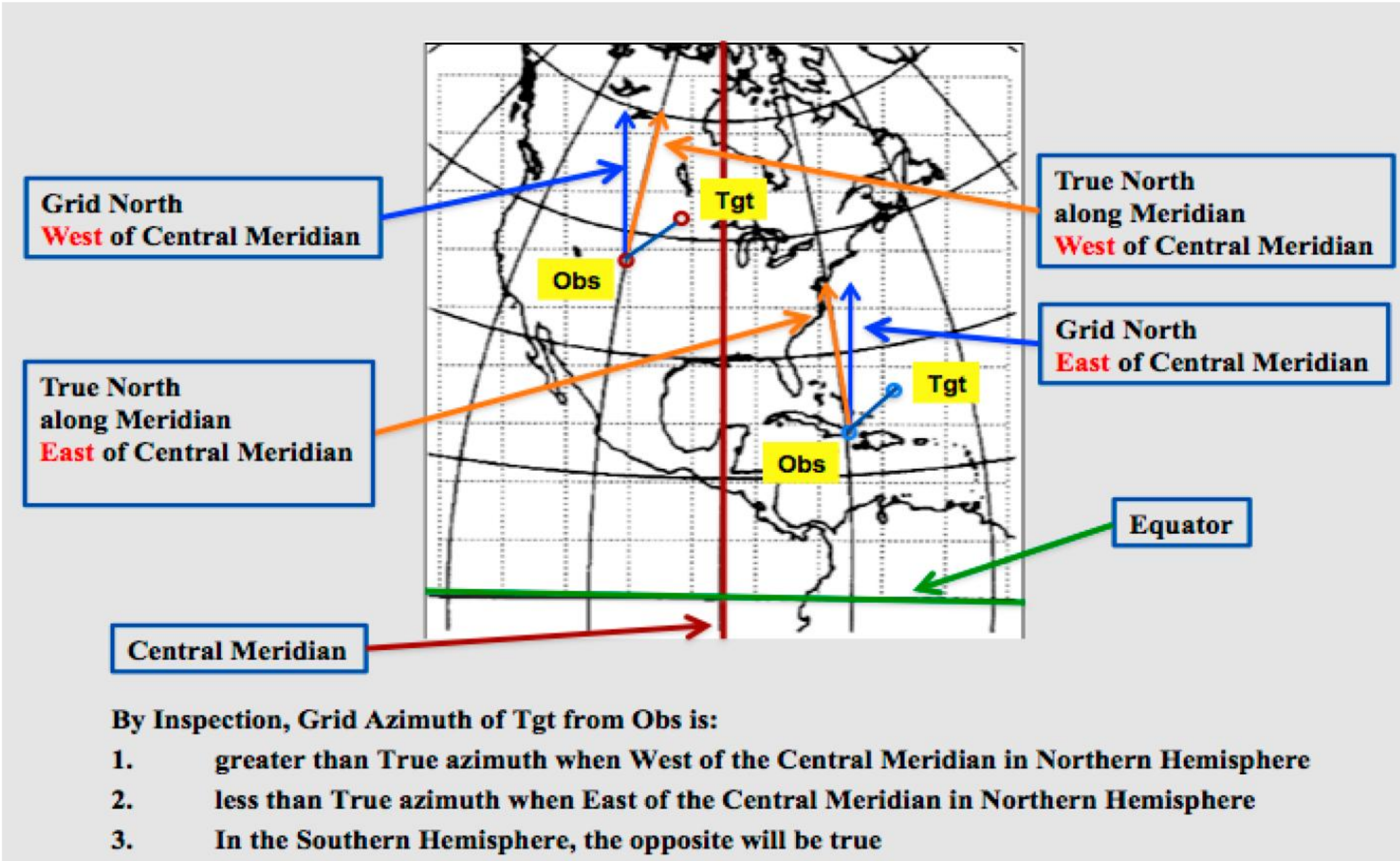


Figure 6. The principle of convergence – the relationship between grid north and true north.

Figure 7. Boundary delineation from private and State sources, with disagreement up to 500 feet.

Figure 8. The misplacement of wells due to improper boundary locations in the computer map.

Figure 9. Shows how incorrect boundaries lead to ‘stretching’ of leases and excess royalty payments.

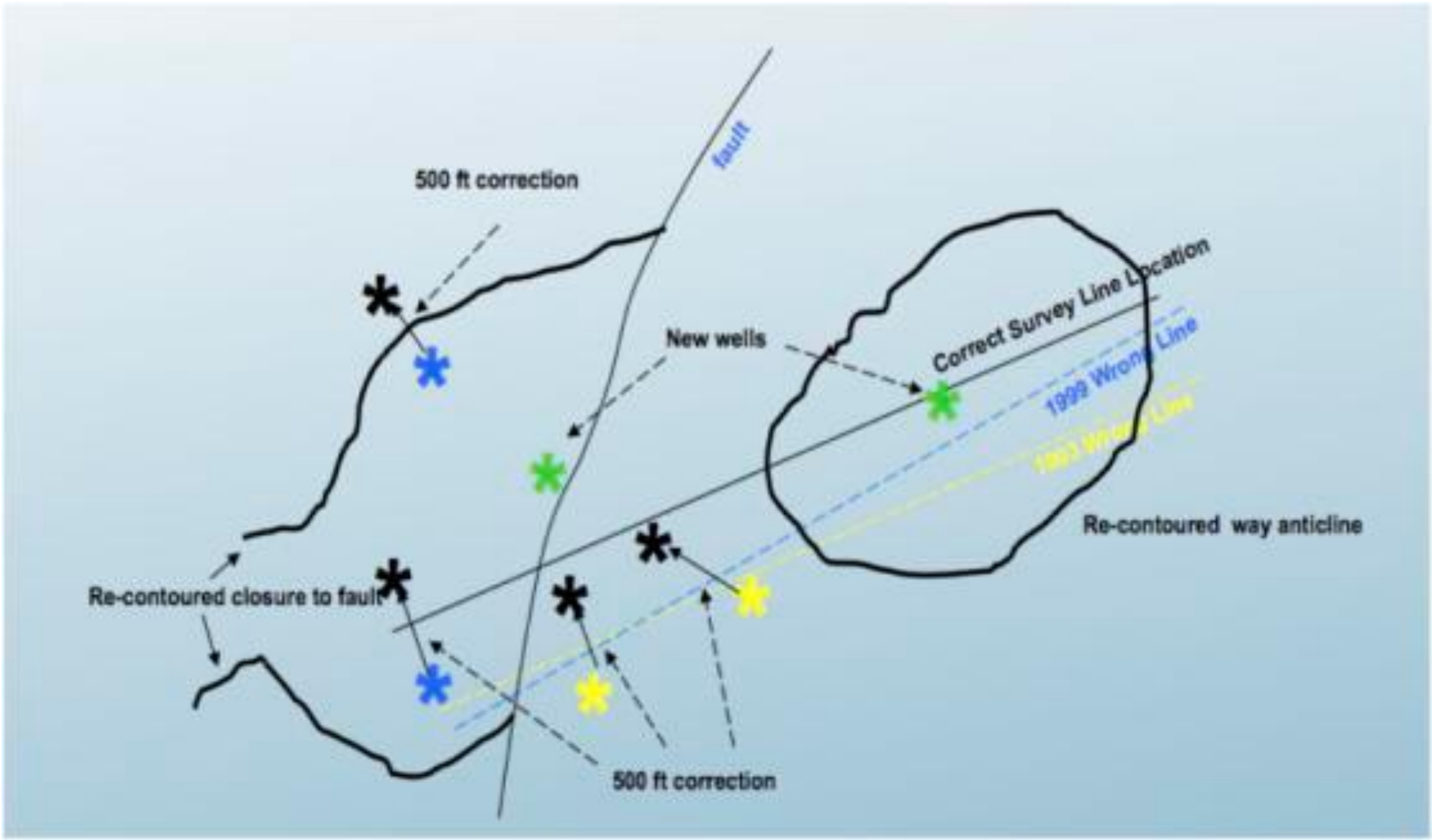


Figure 10. A case of incorrect boundary mapping that could have led to the aborting of the prospect before it was drilled.

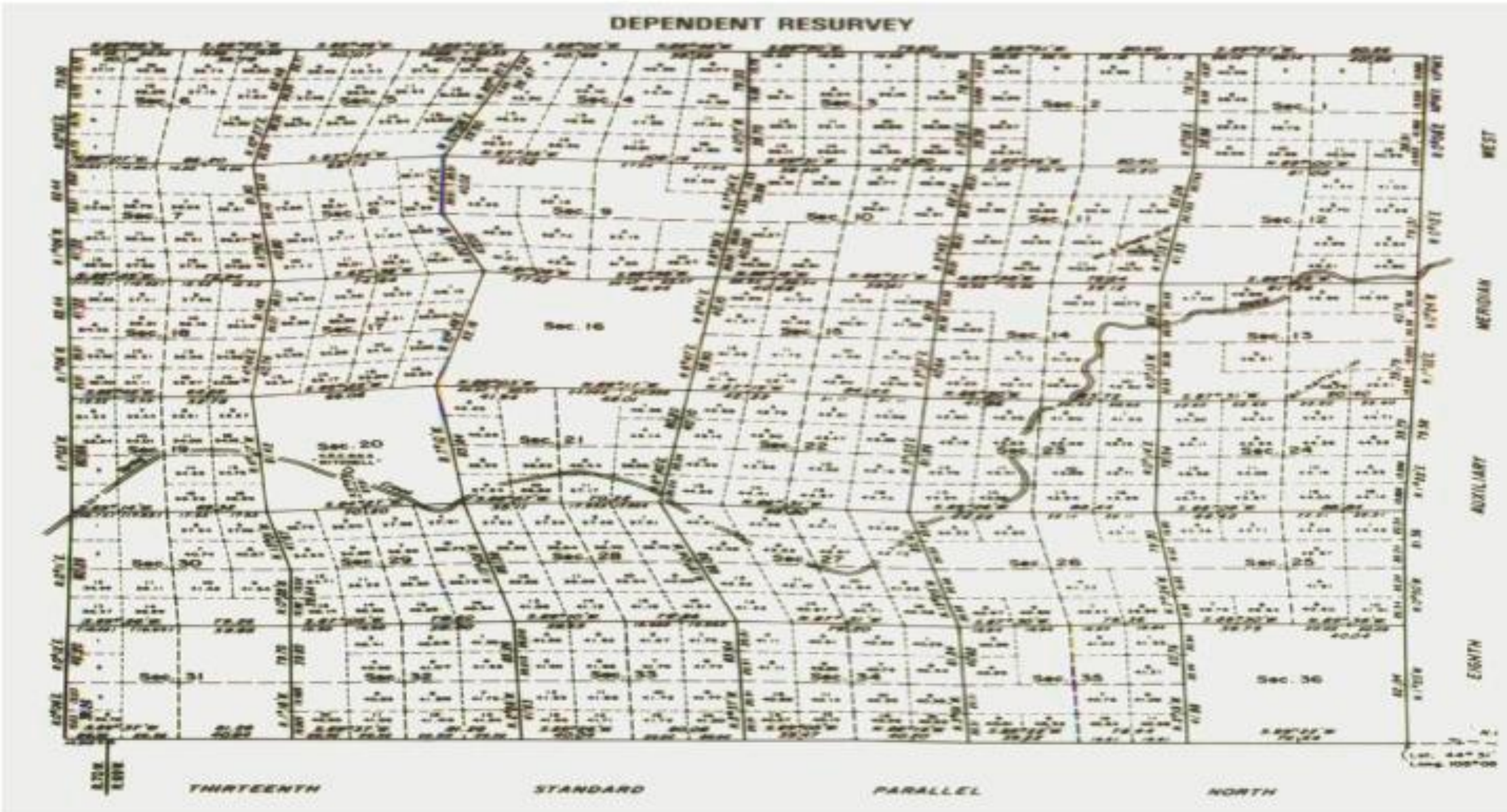


Figure 11. A dependent resurvey of a township in Wyoming. Do not assume that section corners can be interpolated from USGS or other maps.

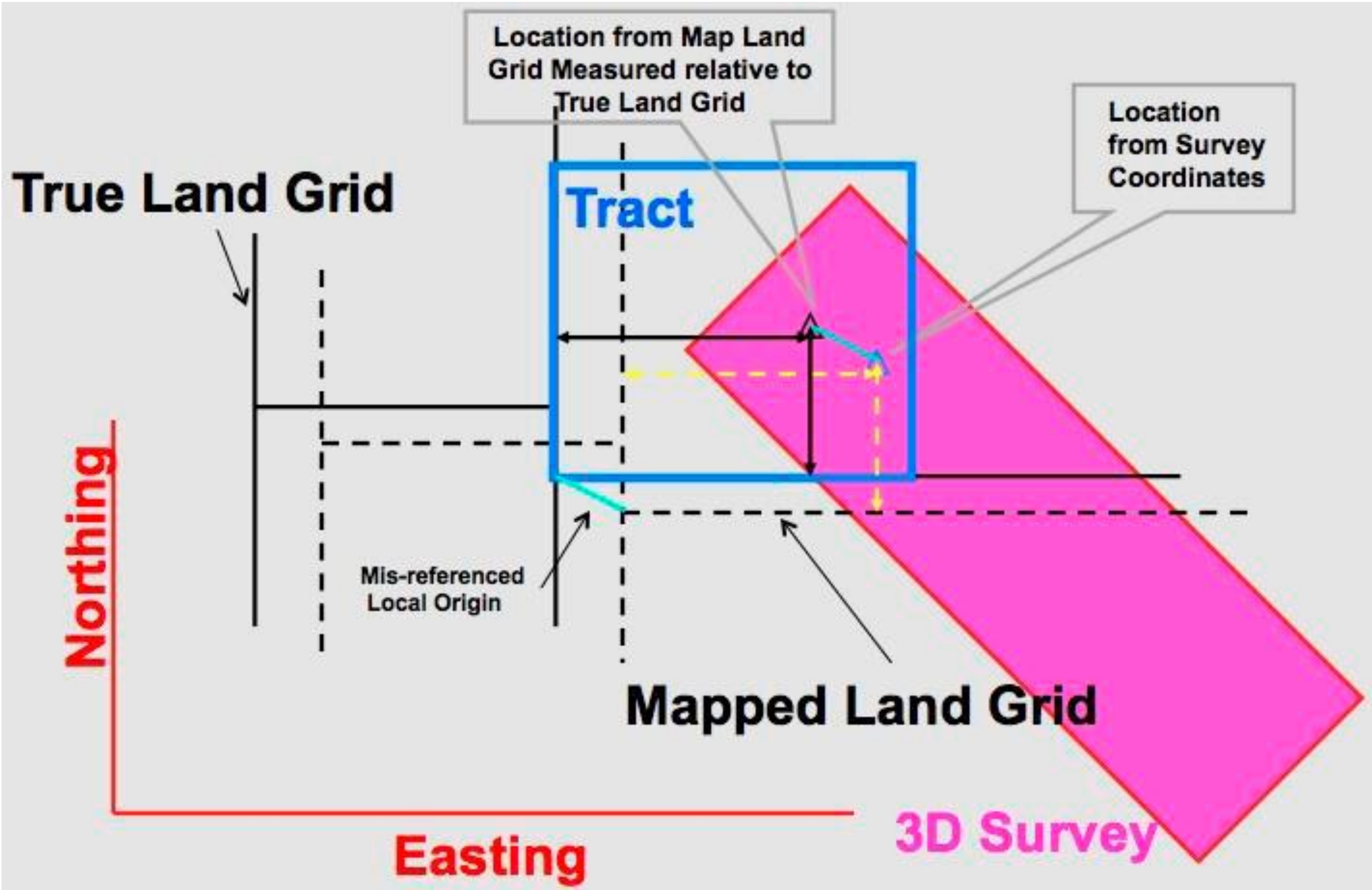


Figure 12. Showing how a decision to survey a well based solely on the boundary distances can go wrong if the boundaries are improperly mapped.

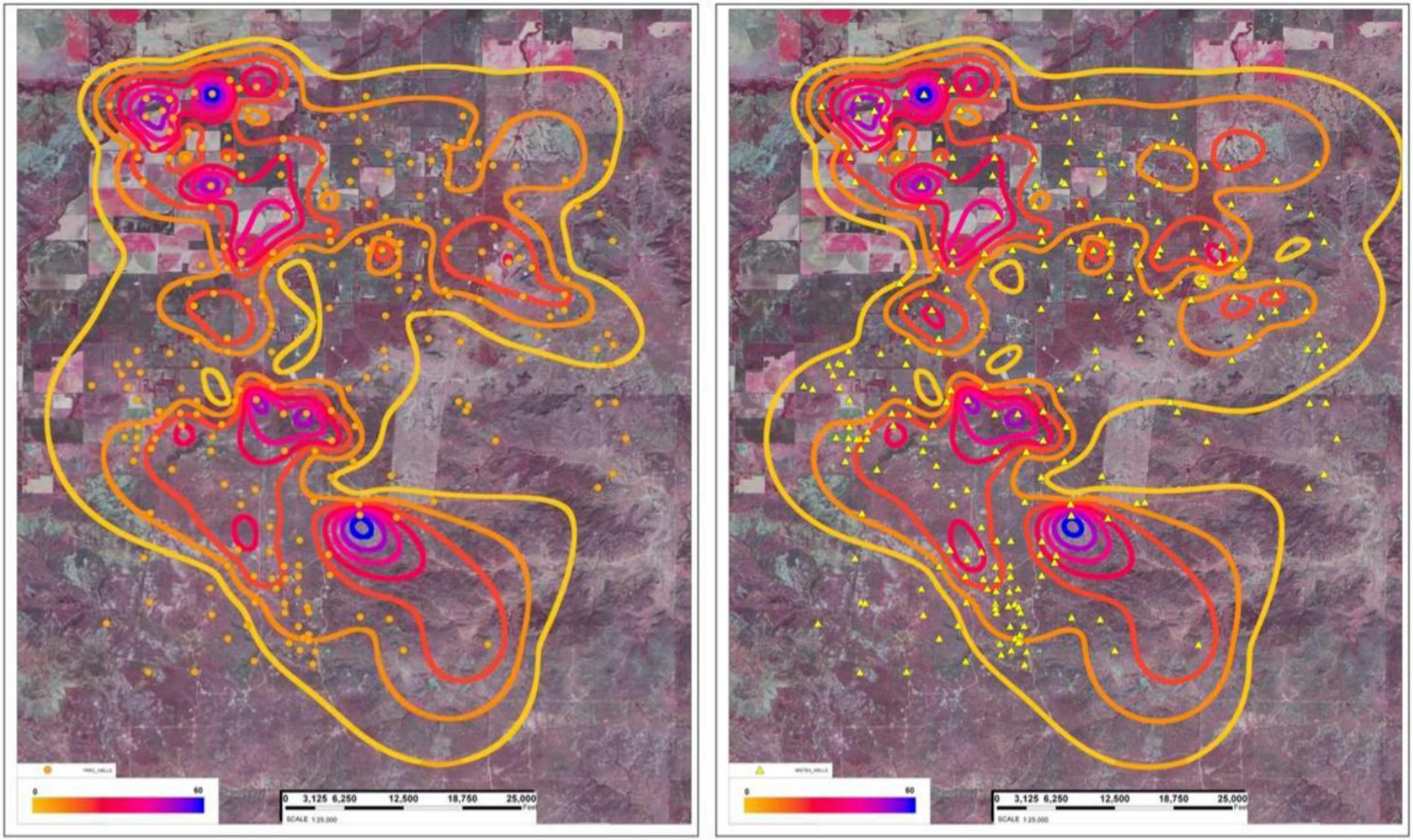


Figure 13. Showing (left) the contours using the TRRC data, and (right) the contouring using resurveyed surface well locations.

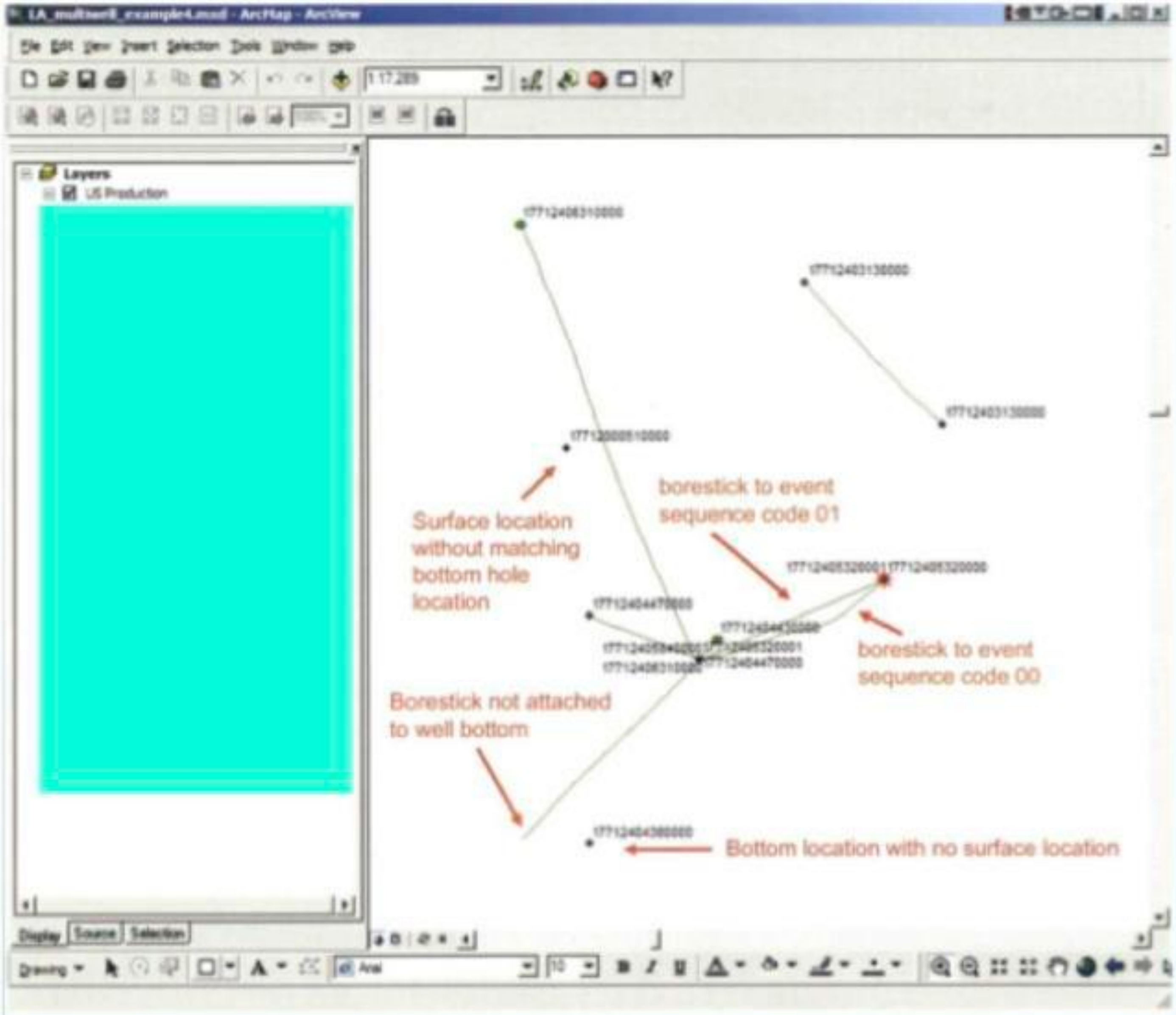
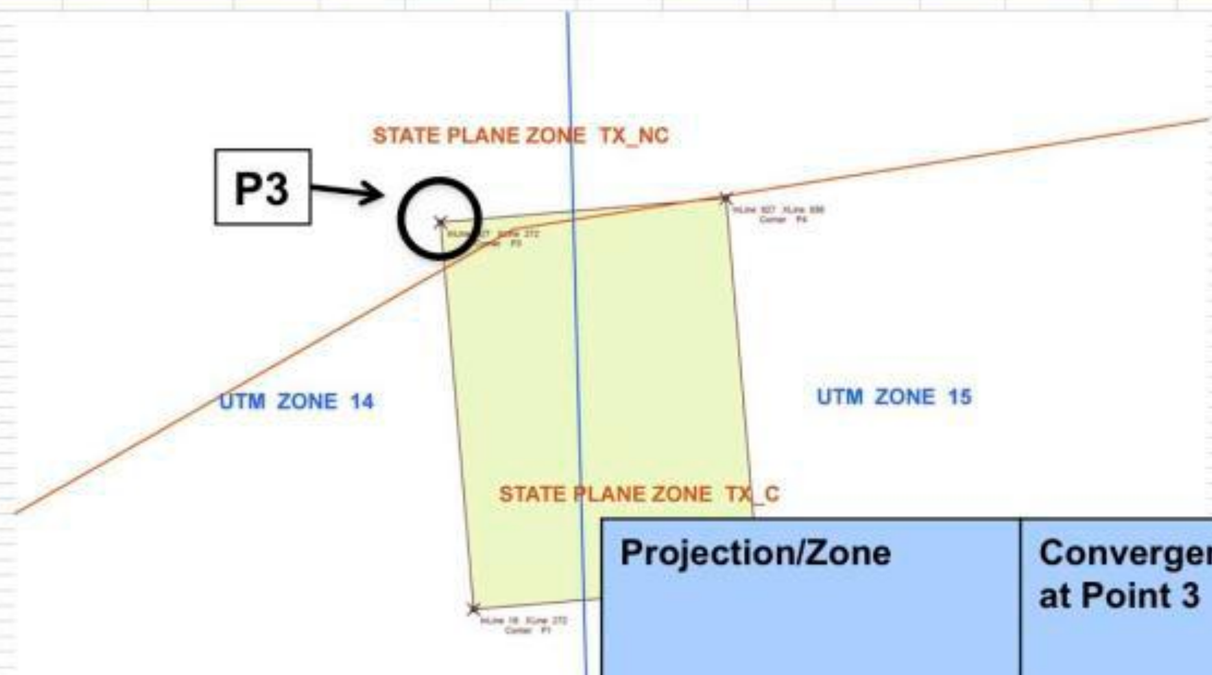


Figure 14. Vendor surface and bottom hole well locations.

CORNER	INLINE	XLINE	X_TxC	Y_TxC	SF_TxC	Conv_TxC	X_TxNC	Y_TxNC	SF_TxNC	Conv_TxNC	X_utm14	Y_utm14	SF_UTM14	Conv_UTM14	X_utm15	Y_utm15	SF_UTM15	Conv_UTM15
P1	18	272	3319642.20	781983.32	0.99996636	2.18537559	2438254.15	32389.37	1.00012913	0.76880499	2544743.92	11536274.03	1.00053716	1.53207536	679891.55	11536823.75	1.00066720	-1.62737487
P2	18	936	3391346.99	788975.00	0.99996896	2.30620920	2511120.84	37586.80	1.00012468	0.89675430	2617570.62	11541442.25	1.00069421	1.65631062	752944.91	11538968.36	1.00050255	-1.50416142
P4	927	936	3381775.54	888506.07	1.00004376	2.29697151	2504000.44	137330.36	1.00002917	0.88697254	2609112.32	11641142.36	1.00067528	1.65956378	750017.60	11638965.86	1.00050846	-1.52530691
P3	927	272	3309070.76	881514.38	1.00004623	2.17623136	2431146.11	132134.41	1.00003269	0.75865394	2536293.66	11634959.43	1.00051968	1.53402053	678968.76	11638837.18	1.00066366	-1.64983462



Projection/Zone	Convergence at Point 3	Rotational Error at 10,000 ft offset
Texas/Central	2.18	284 ft
Texas/North Central	0.76	Correct
UTM/14N	1.53	Correct
UTM/15N	-1.65	636 ft

Figure 15. A field that has structures and objects in both Texas North Central and Texas Central State Plane Projection zones. The error in wellbore location is caused by selecting the wrong convergence.

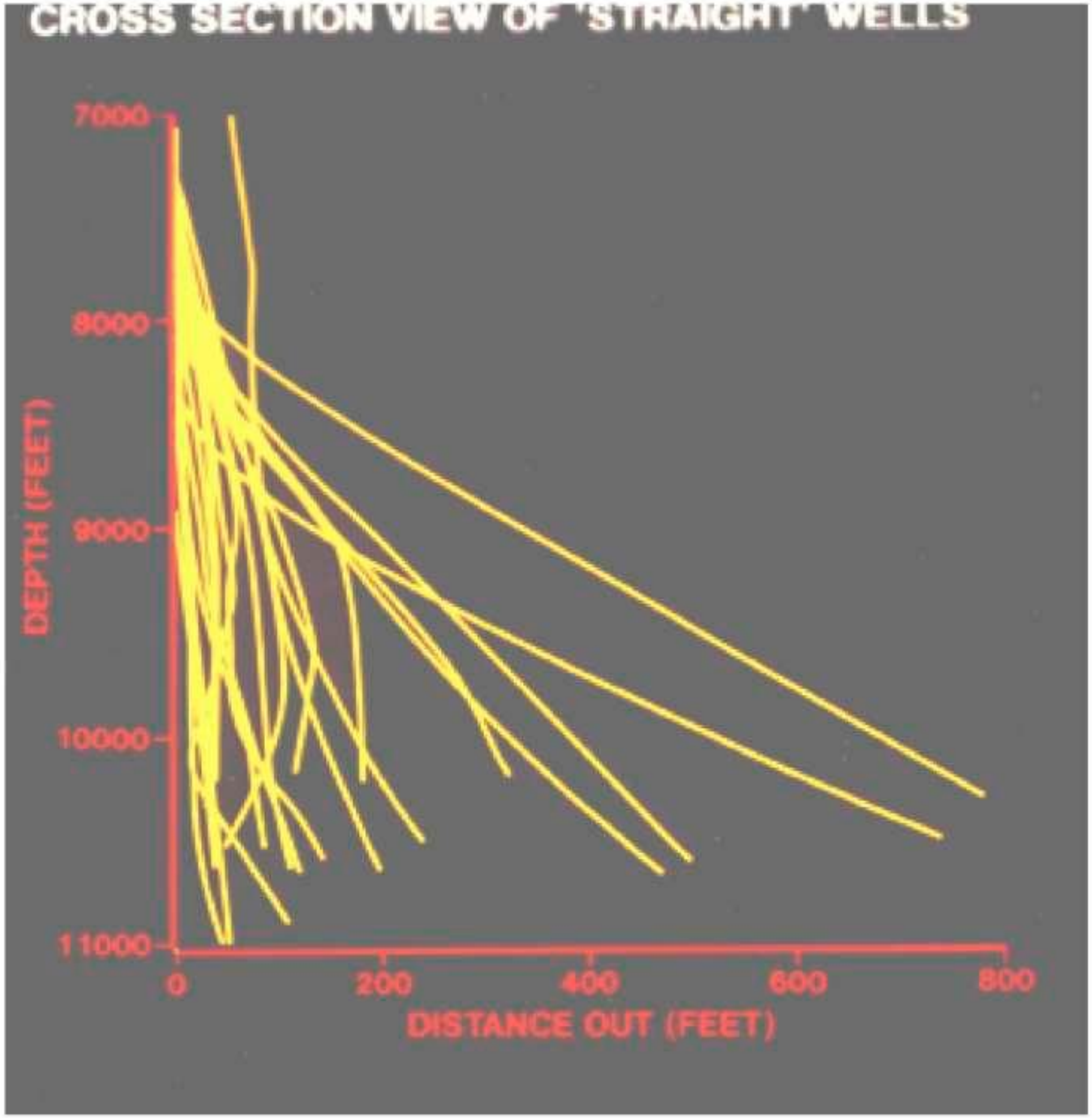


Figure 16. Actual data graphed of reportedly straight wells in West Texas.

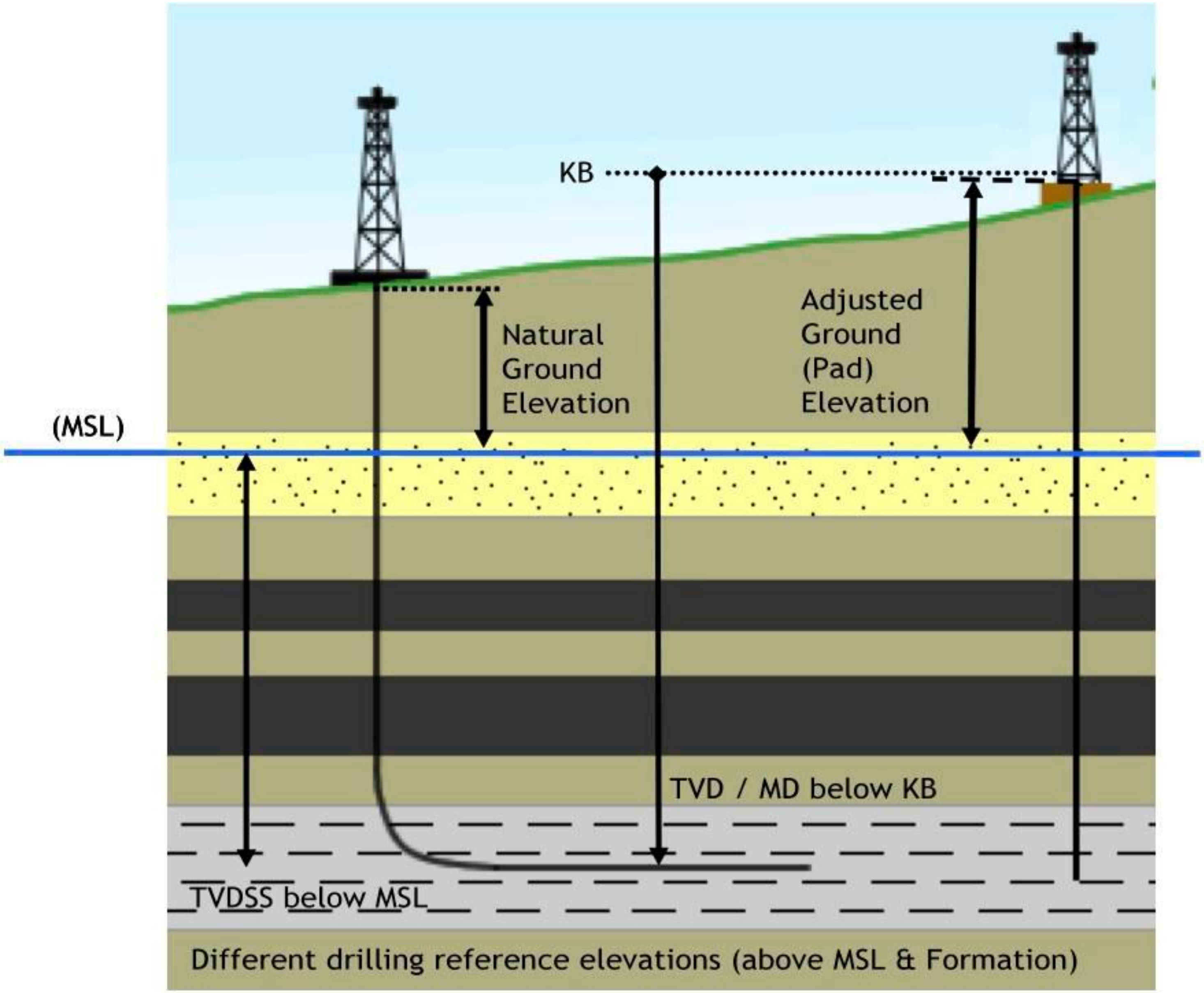


Figure 17. Elevation and depth references.

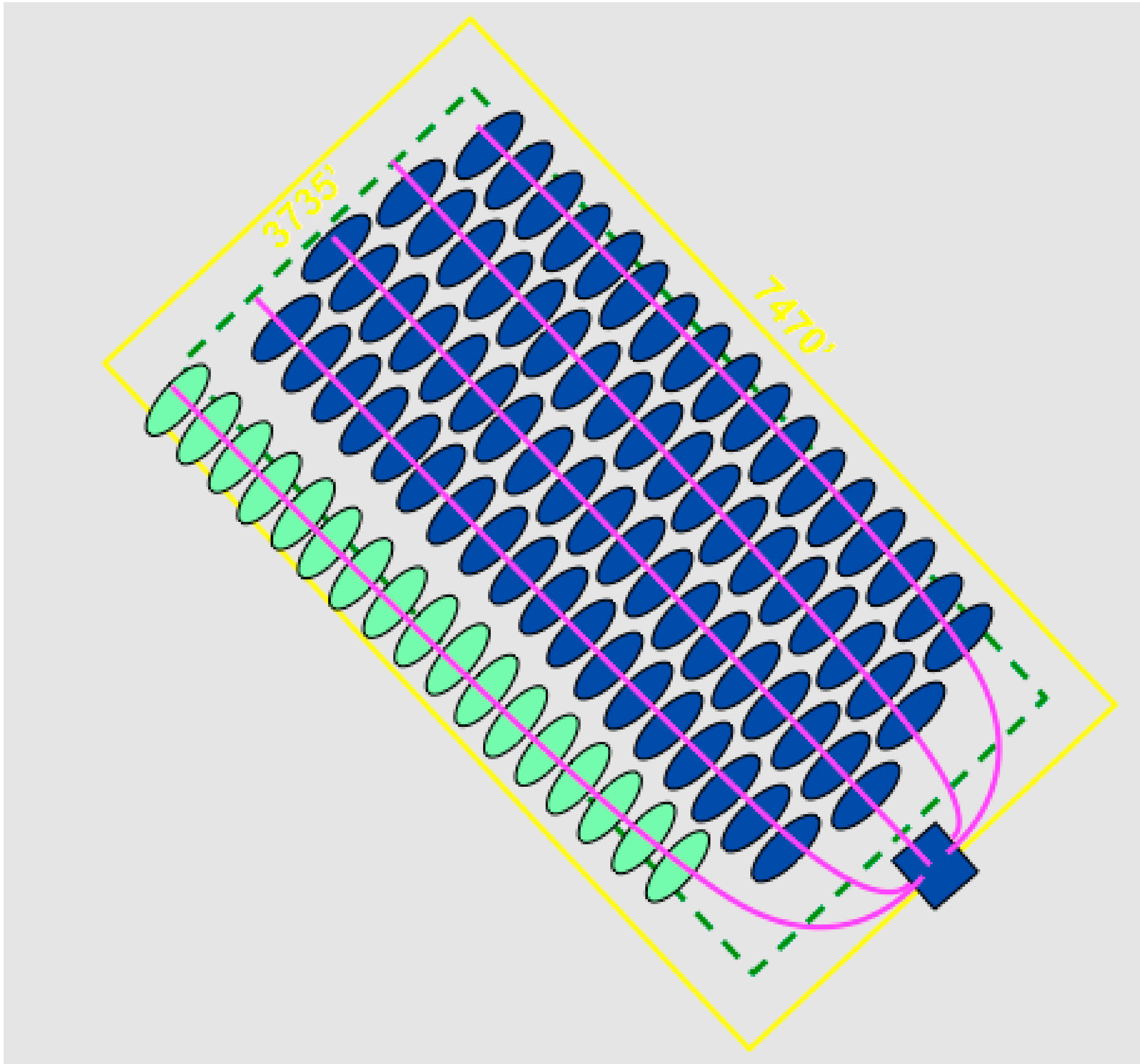


Figure 18. Lost drainage due to a wellbore azimuth referencing problem.

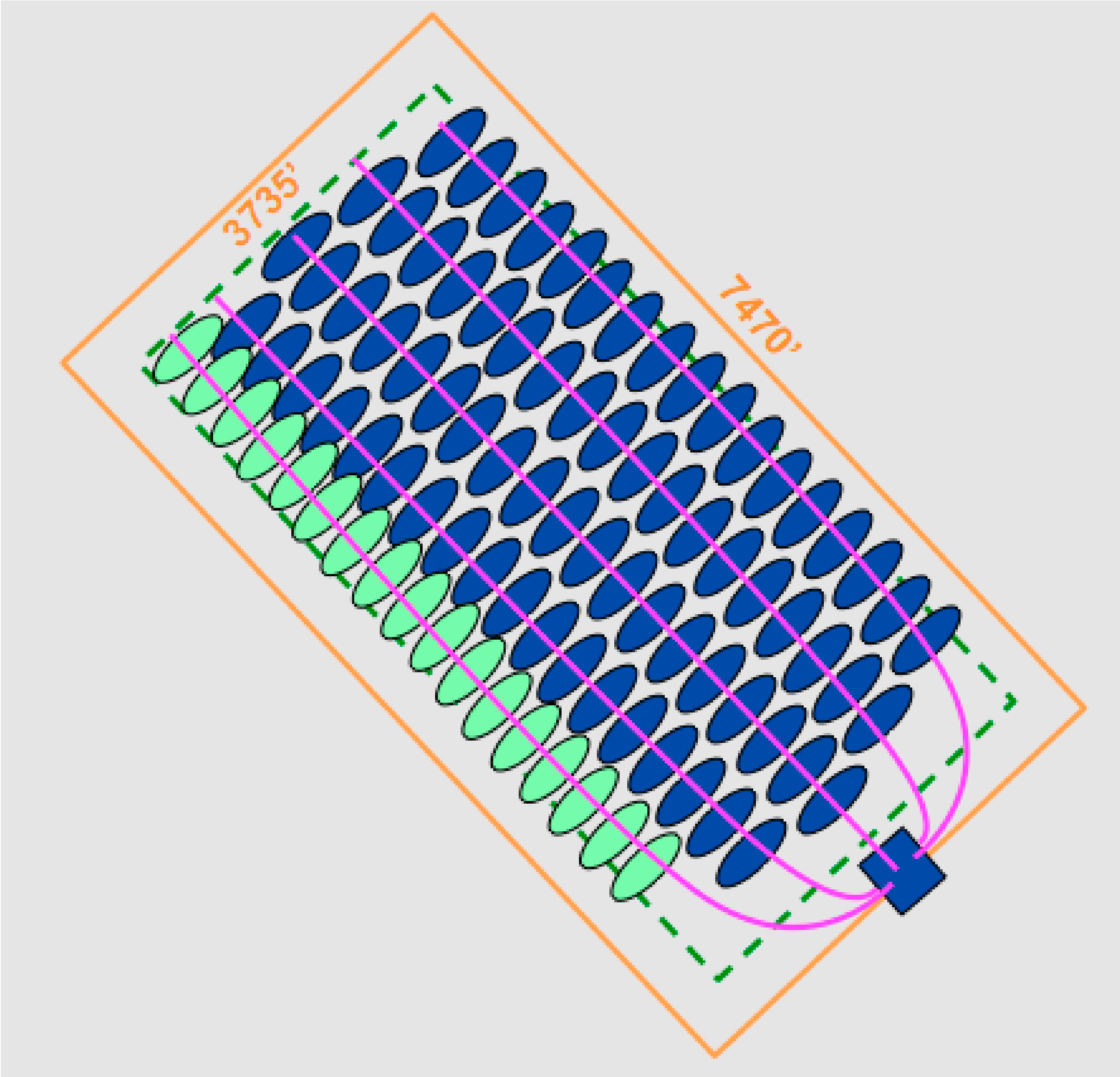


Figure 19. Frac interference due to wellbore azimuth referencing problem.

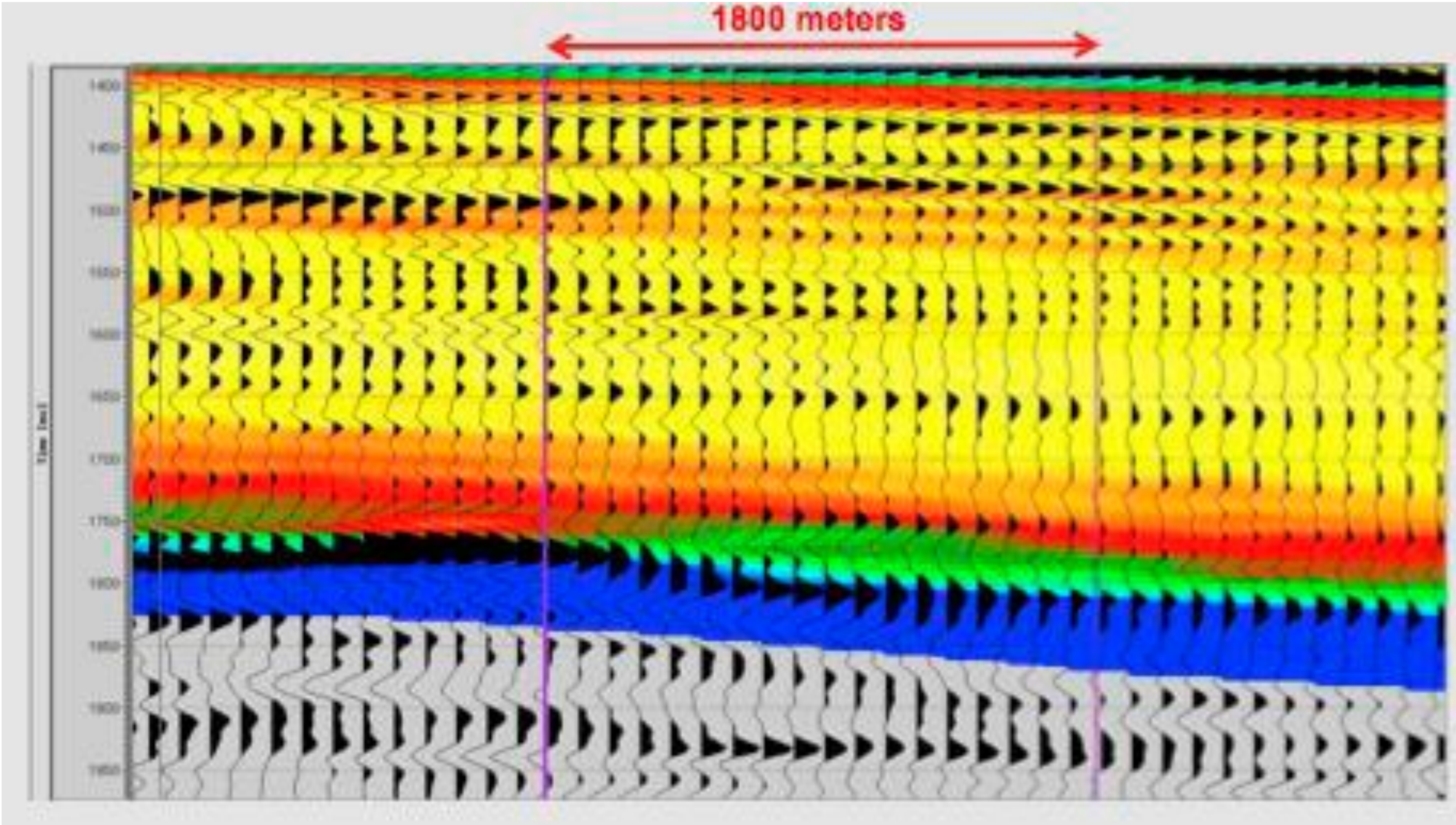


Figure 20. A seismic data inversion where 45% of wells were miss-positioned by more than 250 meters.

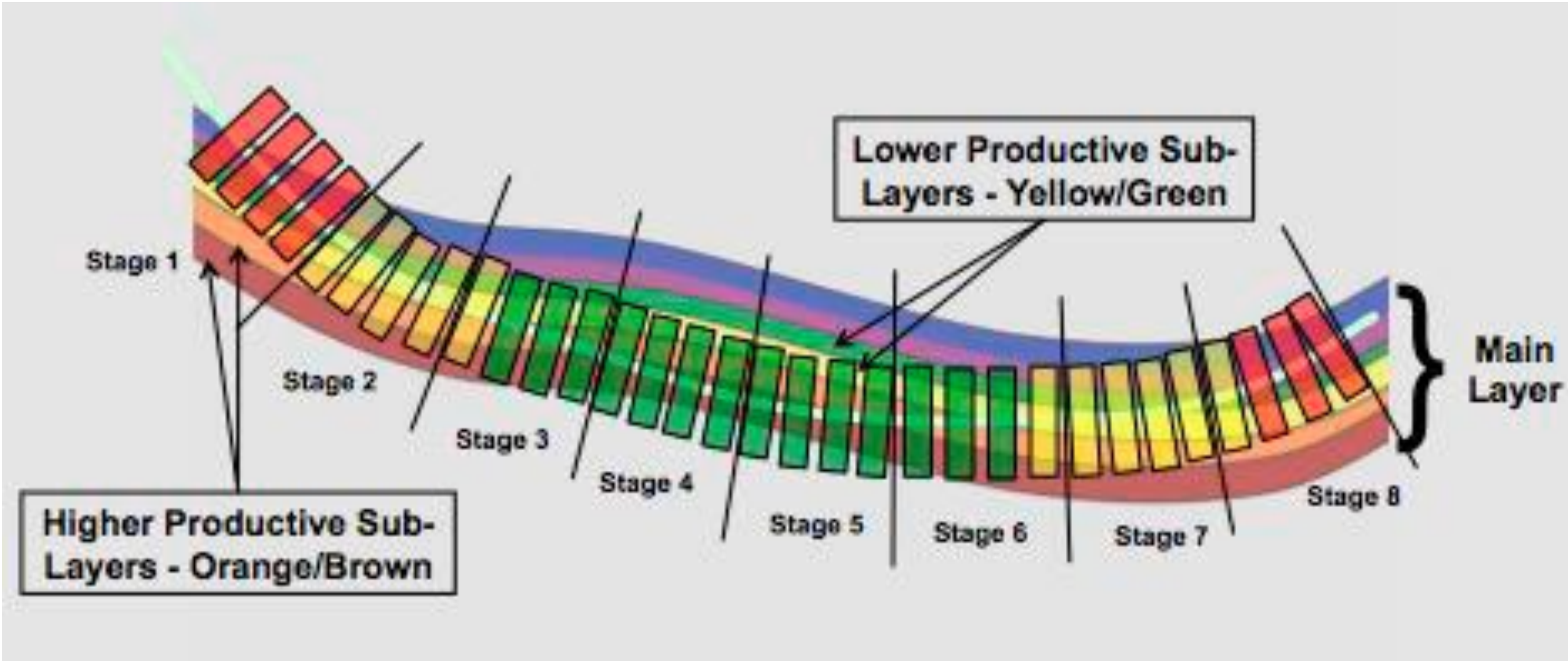


Figure 21. Regularly spaced hydraulic fracturing stages from which perhaps 85% of production is coming from 45% of the stages. SPE article 138427 recommends use of LWD to identify the higher production zones and reduce the frac stages. Is the well positioning data for surface and wellbore good enough to recover the locations accurately enough for this to be an effective strategy?

Reference Name	Description
Geoid	Equipotential Surface of the Earth's gravity field, which is everywhere perpendicular to the direction of gravity and which best fits Mean Sea Level, locally or globally
Geodetic Datum	An ellipsoidal coordinate system that is attached to the earth at some point. e.g. North American Datum of 1927 – NAD27 (Clarke 1866 ellipsoid attached at Meade's Ranch, Kansas) and North American Datum of 1983 – NAD83 (Global Reference System GRS80 Ellipsoid attached to the earth's center of mass (± 2 meters)
Coordinate Reference System	A Coordinate System that has its position, scale and orientation defined with respect to a physical object. In geodesy, a geodetic datum is that which describes a coordinate reference system attached to the earth
Ellipsoid	A geometric shape formed by revolving an ellipse about its minor axis. The term is used interchangeably with spheroid. The most commonly used ellipsoids in North America are: Clarke 1866 Geodetic Reference System of 1980 (GRS 80) World Geodetic System of 1972 (WGS 72) World Geodetic System of 1984 (WGS 84).
Coordinate System	Set of rules for how coordinates are assigned to points. An ellipsoid is a coordinate system
Map Projection	The action that converts geographic coordinates to plane coordinates (easting and northing)
Lease or Unit Boundary Corner	The corner where two boundaries at different azimuths intersect used as an origin for measurements within the unit or lease
Well Surface Location	The surface location of a well used as an origin for wellbore surface offsets. Usually offsets are measured in delta easting and delta northing and delta TVD
Rectified Raster Imagery	A satellite, aerial or Lidar image that is 'ortho-rectified' to ground truth maybe used to check the integrity of the location of visible features such as rig locations, culture such as roads, rivers and buildings
Header Files	The header component of data files containing coordinates used to define the reference information for the data described, including spatial references, naming of objects such as wells, seismic surveys and logs, the timing of operations such as spud date and completion dates, software and versions used for calculating data, tracking of data quality, data handling and movement as well as the personnel and companies implementing such operations.
Heading References: True North, Magnetic North, Grid North, Gyro North, CAD North	True North is the direction of a meridian line through a point. Magnetic North is the direction of the magnetic north pole through a point. Differs from True North by the 'Declination', which is a value east or west that varies with time and is therefore date dependent. Grid North is the direction of the north south grid lines on a map. Differs from true north by the 'Convergence' angle. Gyro North is the 0° heading of a north-seeking gyro. Differs from True North by the 'Gyro Correction'. CAD (Engineering) North is east and increases counterclockwise.
Length/Area Measurements	The International Meter is the international standard of length. The US survey Foot is defined as 0.304800610 of a meter. Other foot lengths are International foot, British foot, statute mile, Chain (~66 ft). 1 Acre is 10 Chains^2
Vertical Datum	Datum describing the relation of gravity related heights or depths to the earth. Mean Sea Level is commonly used reference for elevations, often considered to be approximately the location of the geoid. Chart Datum is often used for depths on navigational charts to show the least depth of water likely to occur. GPS Heights are referenced to the ellipsoid.

Table 1. Common spatial references used in oil and gas surveying and mapping, all critical to accurate mapping.

Object Type	Number of Studies	Number of Objects	Misplaced by over	Percentage Misplaced
Seismic Data	N/A	>1,000 Surveys	100 ft	20%
Surface Well	12	12,000 Wells	100 ft	40%
Bottom Hole	1	534 Wells	200 ft	25%
Boundary	10	>500	100 ft	30%

Table 2. Summary of some studies done on seismic, well and boundary data, and the percentages of data misplaced in our E&P projects and databases. These studies encompass land and marine, international and domestic, proprietary and speculative (and/or multi-client).

Sigma Value	Defect Level (ppm)	% Resources (Wasted)
1	691,462 (31% Error Free)	>50%
2	308,538 (69% Error Free)	40%
3	66,807 (93.3% Error Free)	30%
4	6,210 (99.4% Error Free)	20%
5	233 (99.98% Error Free)	15%
6	3.4 (99.9997% Error Free)	<10%

Table 3. Defect percentage versus resources wasted.

Data Type	Sigma Value	% Resources (Wasted)
Boundaries Worldwide	1.8	42%
Boundaries Lower 48	1.5	45%
Older Seismic	2.0	40%
Newer Seismic	3.1	29%
Well Surface	3.1	29%
Well BHL	2.3	37%

Table 4. The actual impact of the studies with respect to each type of data, by applying the Table 3 standards.