UNDERLYING IMPORTANCE OF GEODETIC SYSTEMS IN HYDROCARBON EXPLORATION

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ABSTRACT

The oil companies’ need to accurately know the geodetic and coordinate projection systems used for their huge amount of digital data has never been so great. This is critical to the studies performed by geologists using specialty software.

Advances in digital cartography, satellite positioning systems, and overall hardware and software have speeded up and facilitated graphical deployment of georeferenced data, map construction, and a myriad of additional applications such as topological, spatial, and tracking analyses, stereoscopic analysis of satellite images, selection of analogs, projections, transformations, geoprocessing, geological and geochemical modeling, seismic and geological interpretation, etc.

As capture and management of data for hydrocarbon exploration improved, the complex geodetic issue—though apparently less important than geologic risk—was brought about.

INTRODUCTION

Geosciences focused on hydrocarbon exploration generally disregard a critical issue which concerns data collection from the topographic surface. That is to say, the reference geodetic system in which data coordinates were derived, where data is understood to be any georeferenced element including, but not limited to, the polygon delimiting an exploration area, the shotpoints defining a seismic line, the contact lines between geological formations, or, most importantly, the point identifying the location of a proposed exploratory well.

A geodetic system is understood to be a network of points with high-precision coordinates on which measurements and locations of any data to be identified are supported. A variety of geodetic systems are available. Failure to clearly identify the geodetic system(s) used in a digital database metadata can result in a shift of approximately 50 meters (up to 600 meters).

Geologists usually have all the elements required to propose an exploratory well which is most likely to prove successful. However, if such elements—including detailed geologic mapping, hypsometry, seismic planimetry, delimitation of the study area, satellite imagery, and digital zone-elevation model—involves unspecified geodetic systems, that is to say systems that are unknown to the user, the formation target to be reached in order to access a potential hydrocarbon reservoir may be completely wrong, which in turn may lead to the waste of money spent in well drilling.

Systematically attributing a dry exploratory well to the exploration risk of an area is the main issue of concern. Failure is thus justified on perfectly valid geological grounds inferred from risk analysis. In petroleum geology, it is well known that no matter how low risk indicators may be, what occurs at depth is not actually known until drilling operations are conducted. That is, it is uncertain whether hydrocarbons are still trapped in a structure, as shown by seismic data, or have migrated elsewhere. However, a dry well resulting from selecting an incorrect surface location or from failure to exercise due care when choosing a geodetic frame is no valid reason from an exploration risk perspective.

The aim of this paper is to clarify a few geodetic concepts, describe the reference systems and reference frames of use in the countries where RepsolYPF operates, demonstrate the “underlying” importance of geodetic systems in hydrocarbon exploration and, ultimately, help minimize the influence of typically unaccounted for and difficultly quantifiable “risk” on the exploration activity.
THE REAL WORLD AND ITS APPROXIMATIONS

The real world we live in, the planet called Earth, is not a perfect sphere nor is its surface even. On the contrary, it is an irregular body, slightly flat at the poles owing to its rotating movement around its axis, its surface being completely uneven. To such an extent, that its real shape has never been given a name. Therefore there is no mathematical expression to define the true shape of the Earth.

But owing to the fact that geosciences and geotechniques need to know the best approximation to its true shape, to position and represent on a map the geographical and cultural accidents on its surface, and the phenomenon produced on it, they have adopted diverse approximation bodies. The first is the Geoid, a physical model because its figure is the result of the force of gravity. The Geoid is a surface of constant gravitational potential (equipotential). It is represented by the calm seas extending under the continents. The level surface of the geoid’s gravity field is undulated because the gravitational attraction is proportional to the differences in the landmass. The surface of the Geoid is the one which best fits the mean sea level, and is the reference surface when performing leveling work, in other words, to establish the altitude or elevation of any point.

However, the mathematical expression defining the Geoid is too complex and impractical for positioning, coordinate calculating, and mapping purposes, to be able to represent the different phenomenon, accidents and events occurring on the surface of the Earth on a map. Thus, to simplify the problem, a second approximation surface was adopted, i.e. Ellipsoid (or Spheroid), which is a pure mathematical model defined by a revolution ellipsoid that turns around its polar axis, producing a flattening of both poles, analogous to that of the real Earth. The advantage of this is that the surface of the ellipsoid is completely even.

With the passing of time and due to the improvement of measuring instruments, different ellipsoids were calculated, improving precision and making it more approximate to the area of the land surface where measuring and positioning work was being carried out. Therefore, until the advent of satellite geodesy, a group of countries adopted the Ellipsoid which best fitted their needs. The attached table shows some of the best-known ellipsoids, with their two defining parameters (semi-major axis and flattening), and the area in the world or group of countries which uses or used it.

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Spheroid} & \text{Semi-major axis} & \text{flattening} & \text{Used} \\
\hline
\text{Airy 1830} & 6377563.396 & 299.34064 & \text{Great Britain} \\
\text{Bessel 1841} & 6377397.155 & 299.32765 & \text{Central Europe} \\
\text{Clark 1866} & 6378206.4 & 293.465 & \text{North America} \\
\text{Clark 1880} & 6378249.145 & 300.8017 & \text{India, Myanmar} \\
\text{Everest 1830} & 6377276.345 & 300.8017 & \text{India, Nepal} \\
\text{Everest 1856} & 6377301.243 & 300.8017 & \text{India, Nepal} \\
\text{Everest 1869} & 6377295.664 & 300.801836 & \\
\text{Fischer 1960} & 6378166 & 298.3 & \\
\text{Fischer 1968} & 6378300 & 298.3 & \\
\text{GRS 1967} & 6378160 & 298.247167 & \\
\text{GRS 1975} & 6378140 & 298.257 & \\
\text{GRS 1980} & 6378137 & 298.257222 & \text{North America} \\
\text{Hayford 1910} & 6378388 & 298.959 & \\
\text{Helmert 1906} & 6378200 & 298.3 & \\
\text{Hough 1956} & 6378270 & 297 & \\
\text{Int. 1909} & 6378388 & 297 & \text{World reference} \\
\text{Krasovsky 1940} & 6378245 & 298.3 & \text{Ex USSR countries} \\
\text{New Int. 1967} & 6378157.5 & 298.249655 & \text{World reference} \\
\text{N. Amer. 1969} & 6378160 & 298.25 & \text{South America} \\
\text{WGS 60} & 6378165 & 298.3 & \\
\text{WGS 66} & 6378145 & 298.25 & \\
\text{WGS 72} & 6378135 & 298.26 & \\
\text{WGS 84} & 6378137 & 298.257223 & \text{World reference} \\
\hline
\end{array}
\]

Just like the Ellipsoid mathematically defines the shape of the Earth from a planimetric viewpoint, there is another element which defines the orientation and position of the Ellipsoid with respect to the center of the Earth: the Datum. This is a real physical point materialized on the topographic surface, where the perpendicular to the ellipsoid and the local vertical (in respect to the geoid) coincide. In other words, at that point the geoid and ellipsoid surfaces are tangential. The Datum is the fundamental point and the origin of a traditional geodetic grid. To be able to establish its location, a site was determined possessing certain conditions, such as absence of magnetic disturbances, few gravity anomalies, and minimum potential deviations from the vertical, among others.

But the speed of progress in satellite technology during the last two decades precipitated a “new world geodetic order”, and a new discipline arose: satellite geodesy. With the worldwide use of GPS equipment, the term WGS (World Geodetic System) spread rapidly. This is an ellipsoid and at the same time a geodetic and geocentric reference system developed by the former US DMA (Defense Mapping Agency). It is also defined as a conventional land system with X Y Z coordinates origin at the center of Earth’s land masses. The Datum point concept, as defined in classical geodesy, ceased to exist, and was replaced by a “geocentric Datum”, giving rise to the group of three geocentric Cartesian orthogonal coordinates. Since its first version in 1960, the WGS ellipsoid has been gradually upgraded, (1966, 1972) until its 1984 version, the WGS84, was developed, the use of which has spread widely owing to the fact that it is the one used by global positioning systems (GPS).

To mathematically link locally used ellipsoids in relation to the geocentric WGS84, Sergei Molodensky, a Russian mathematician, calculated X Y Z constants in meters which define the differences in position of the center of each known ellipsoid with respect to the geocenter (X=0; Y=0; Z=0), the origin of WGS84 coordinates. These constants are an acceptable approximation for general applications. But this is not so for work entailing higher precision.
GEODETIC SYSTEMS AND REFERENCE FRAMES

As mentioned above, geosciences and geotechniques in general and hydrocarbon exploration activity in particular involve knowing the location of the elements on the ground surface for subsequent mapping, study and analysis. Thus, in order to know the georeferenced coordinates, preexisting geodetic networks should be used. Geodetic networks are the result of complex mathematical calculations and extensive field work.

Here, the conceptual differences between a reference system and a reference frame should be highlighted. A reference system concerns the theoretical physical-mathematical conception involved in choosing a reference ellipsoid, defining an origin by determining a datum, and defining ellipsoid orientation through a data point azimuth. On the contrary, a reference frame is the physical materialization, on the ground, of the points in a geodetic network. This should honor the theoretical conception of the system chosen as accurately as possible.

In the traditional geodetic systems, the reference frame consisted of trigonometrical points which formed main chains generally following meridians and parallels to give rise to a grid. In geocentric systems, accurate data points are materialized using GPS systems to form a primary network which is usually supported on existing points from previous local networks.

Regardless of the reference frames used, the problem lies in the different origins of such reference frames. Old systems orientated the reference surface (ellipsoid) according to the datum point selected in each zone. As a result, one and the same point has different coordinates depending on the origin involved. However, in all cases, as these are plane systems, the coordinates of a point and the discrepancies between systems will also be plane since all systems are tangential to the Earth’s surface.

On the contrary, if we compare the coordinates of a point between a local (planimetric) system and the world geodetic system (WGS84), the differences between both systems will be geocentric in nature with respect to the X, Y, Z, coordinate set and will reflect changes in ellipsoidal parameters.

Several formulae are available for systems transformations. Molodensky’s formula using 3 parameters for ΔX, ΔY and ΔZ translations between the origins of both systems is the most widely used approach. The formula involving 7 parameters, in addition to the above three translations, uses 3 Rx, Ry, Rz rotations around their axes and a scaling difference S resulting from differences between ellipsoids. However, for practical purposes, it is sufficient to use Molodensky’s constants.

HYDROCARBON EXPLORATION AND GEODETIC SYSTEMS IN ARGENTINA

The origins

Oil exploration in Argentina began in 1903 with the drilling of the first well in the San Jorge Basin located in Patagonia, that is to say, a long time before IGM (Military Geographic Institute) geodetic crews managed to develop a unique high-precision reference geodetic network for the whole country. For the first well drilled, 1 was taken as the point of origin and 0.0 served as a primitive plane coordinate system.

Thus, all geodetic work undertaken in each basin in which production operations were conducted served as a basis for early exploratory activity. Old well records with well coordinates referenced to other wells or to elementary rectangular systems, such as Pampa Minerales, Mina, etc., are still available.

In 1948, the IGM published a book on provisional coordinates expressed in the Castelli datum (probably the oldest geodetic system materialized in Argentina in the first decade of the 20th century), with the following preface: “Early geodetic work in the country could not be conducted as rationally as technically desirable, since it was conducted in different areas as local needs arose and, when extended and integrated, exhibited discrepancies resulting not only from errors in observations but also from deviations from the vertical, which are typical of the different origins used.” This system provisionally gathered together all geodetic work by then conducted in the provinces of Buenos Aires, Córdoba, Corrientes, Entre Ríos, Mendoza, Misiones and San Juan in Argentina.
The following systems are contemporaneous with the above referred datum: Yavi in the province of Jujuy; Chos Malal in the province of Neuquén, Pampa del Castillo in the Golfo San Jorge area which was not tied to the Castelli datum; Ubajay on the banks of Uruguay River, i.e. the international boundary with the homonymous country.

Following enactment of the first Mapping Act (1941), the IGM created other local systems in response to the needs of the time. These were isolated systems too: Tapi Aike in the province of Santa Cruz (1945); Huemules in the province of Chubut (1947); Carranza in the province of Catamarca (1952); 25 de Mayo in the province of San Juan (1962).

In turn, other organizations such as the Servicio de Hidrografia Naval (Naval Hydrography Service), the Comisión Nacional de Límites (National Boundary Commission) and YPF (the state-owned oil company) also conducted geodetic work. The Servicio de Hidrografia Naval developed two coastal networks, namely, Ministerio de Marina Norte (or I) and Ministerio de Marina Sur (or II). The Comisión Nacional de Límites created the Hito XVIII 1963 system jointly with Chile. And YPF developed the Aguaray network in northern Argentina and also made existing networks denser. These included Tapi Aike, Pampa del Castillo, and Chos Malal – Quiñí-Huao.

Local Systems

As from early 1940’s, drilling of exploratory wells began to grow and sedimentary basins containing discovered fields increased significantly. Both facts forced the company to place each well to be drilled and delimit each drilling area more precisely.

To that end, the local geodetic networks which had kept pace with exploration activity began to be used for support. Shifting from a lack of support points and primitive systems having little or no accuracy in earlier decades to the “high-precision” networks created by the IGM and by YPF itself with their own teams of topographers and geodesists was a significant jump regarding exploration precision.

The geodetic systems used in each of the five producing basins were as follows:

1-Aguaray system in the Noroeste Basin. Network created by YPF. With planimetric discrepancies from Campo Inchauspe system of the order of +487 m, in the east-west direction, and of the order of -42 m in the north-south direction.

2-Chos Malal – Quiñí-Huao system in the Cuyo and Neuquen Basins. A network initially developed by IGM in 1914 with 56 trigonometric points. Later extended by YPF which called it Quiñí-Huao system. It contained 757 points in the orders of precision established (35 points out of these 757 points are shared with Campo Inchauspe system).

3-Pampa del Castillo system in the San Jorge Basin. Network developed by the IGM and made a bit denser by YPF, with 95 trigonometric points, 3 of which are shared with Campo Inchauspe.

Discrepancies from Campo Inchauspe system total +127.5 m, east-west, and –124.5 m north-south.

4-Tapi Aike system in the Austral Basin (southern Santa Cruz). Developed by the IGM in the 1940s and also made slightly denser by YPF with 258 total points, 30 of which are shared with Campo Inchauspe.

Shifts from Campo Inchauspe system total 84 m, east-west, and 58 m, north-south.

The 3 following systems also pertain to the Austral Basin but they relate to Tierra del Fuego where no Campo Inchauspe network point is available.

5-Hito XVIII in the Austral Basin (Tierra del Fuego). Developed by the Comisión Nacional de Límites.

Shifts from WGS84 datum total -85 m, east-west, and +177 m, north-south.

6-Ministerio de Marina Norte. Austral Basin (Tierra del Fuego). Developed by the Servicio de Hidrografia Naval with discrepancies of -35 m, east-west, and +122 m, north-south, from WGS84 datum.

7-Ministerio de Marina Sur. Austral Basin (Tierra del Fuego). Developed by the Servicio de Hidrografia Naval. Shifts from WGS84 datum: +37 m, along the east-west axis, and +128 m along the north-south axis.

In those years, and for several decades thereafter, all types of well data were collected (wells, seismic planimetry, area delimitation, etc.) using the only geodetic system available in each basin. This may be the reason why the geodetic system in which coordinates were measured was not stated in the different files and reports issued during those days. In
other words, it was taken for granted that it was the only reliable and precise system and by that time nobody could even imagine that another more reliable and precise nationwide system would be developed.

**Campo Inchauspe**

However, a network containing only 10 polygons was created in 1954. Pursuant to official regulations, this would be the only official and national network. This system originated from the homonymous datum located at L. 35°58′16″,56 S and L. 62°10′12″,03 W, in Pehuajó, in the Province of Buenos Aires. The 1924 international ellipsoid is the associated ellipsoid. Network precision ranges from 3 to 10 ppm based on statistical results from partial compensations.

By 1969, it already involved 19 compensated and readjusted triangulation polygons with their astronomic station recalculated. In the late 1980s, it proved to be the most important network in the country with 44 polygons and approximately 18000 trigonometric points covering all of the country’s producing basins. As a result, two systems were available in each basin as from 1970s: the local system and the national Campo Inchauspe system.

Well drilling was a major activity by those times, so it was probably prioritized at the expense of appropriate well placement or surveying. Thus, only rarely was the geodetic system used stated in relevant reports. Early discrepancies between geodetic systems existing by those times are still stored in the huge vector data bases currently managed by the company.

**Posgar Network**

However, the datum shift issue has not been overcome yet. In May 1997, the Posgar 94 geodetic network (Argentine Geodetic Positions) was adopted as the official reference frame and replaced the former Campo Inchauspe national system. The Posgar 94 network is the materialization of the WGS84 system in the country and consists of 127 primary points evenly distributed all over the country (Figure). Its relative precision is of the order of 1 part per million and the accuracy of the geocentric positioning of the system is of the order of 1 meter.

However, while facilitating positioning and improving positioning precision, this technological development also contributed to worsen the situation as it added a third reference system. As a result, each hydrocarbon producing basin in the country currently has:
1-A local network (isolated and constrained to each basin), used as the only reference system available from 1920 to 1970, that is, approximately 50 years.
2-The old official Campo Inchauspe system (for nationwide use), from 1970 to 1998 (28 years).
3-The new official Posgar 94 (global) network, from about 1998 to date (7 years in use so far).

**GEODE蒂IC SYSTEMS IN COUNTRIES WHERE REPOLYPF CONDUCTS OPERATIONS**

Following YPF privatization (1993) and the subsequent arrival of Repsol (1999) which acquired the Argentine company giving rise to a merger known as RepsolYPF, the energy and exploration business expanded into 24 countries. This in turn resulted in an increase in the number of additional geodetic systems and coordinate projection systems stored in the huge digital database managed by the company. The main geodetic issues of concern are shown below with special emphasis on Latin American countries as this paper has been prepared in Buenos Aires.

**In Latin America**

The first attempt to integrate the national geodetic networks of South American countries was called PSAD56 (Provisional South American Datum 1956) and the origin datum was established in Venezuela, Bolivia, Colombia, Ecuador, Guyana, Peru and Chile.

Although discrepancies from points near the origin and in southern Chile were so significant that the whole situation had to be redefined, the PSAD56 network was widely used in hydrocarbon exploration for several decades.
The project was redefined for a unified South American datum in the late 1960s as a joint effort between Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Venezuela and Trinidad-Tobago. It was called SAD69 (South American Datum 1969), the new South American datum point was defined in Chuá, Brazil, and South American 1969 (with parameters almost identical to those of GRS67) was established as the associated ellipsoid. Only a few exploration operations used this system although it was much more precise than the PSAD56 system.

Following is a short description of the geodetic systems identified in the data coordinates of exploration interest, which are in use in the South American countries where activities are currently conducted by RepsolYPF. Molodensky’s constants in meters with discrepancies from the world WGS84 system are also shown.

**In Bolivia.** Three geodetic systems are in use: PSAD56, SAD69 and WGS84. The two former systems have the following geocentric constants with respect to the WGS84 system:

1-PSAD56. Shifts: \( AX = -270; \Delta Y = +188; \Delta Z = -388 \)

2-SAD69. \( AX = -61; \Delta Y = +2; \Delta Z = -48 \)

However, most historical data from wells, seismic lines, and corners of exploration or production blocks is expressed in the PSAD56 system. Some seismic programs seem to have been performed in the SAD69 system. And the WGS84 system began to be used for support about one decade ago.

**In Ecuador.** The above three geodetic systems are in use but its geocentric constants have been fitted to the country. Thus:

1-PSAD56. Shifts: \( AX = -278; \Delta Y = +171; \Delta Z = -367 \)

2-SAD69. \( AX = -48; \Delta Y = +3; \Delta Z = -44 \)

As for data of hydrocarbon exploration interest, the situation is similar to that of Bolivia. Most historical data is expressed in the PSAD56 system.

**In Colombia.** In addition to the two continental systems and the WGS84 system, a third system, the old national system known as Bogota Observatory, is in use. 1-PSAD56. Shifts:

1-PSAD56. Shifts: \( AX = -282; \Delta Y = +169; \Delta Z = -371 \)

2-SAD69. \( AX = -44; \Delta Y = +6; \Delta Z = -36 \)

3-Bogota Observatory. Shifts: \( AX = +307; \Delta Y = +304; \Delta Z = +318 \)

The coordinates of most data of exploration interest are referenced to the latter system. It should also be emphasized that the WGS84 system has been materialized in Colombia as the MAGNA network (National Geocentric Reference Frame) accurately measuring a 60 point-network.

<table>
<thead>
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<th>Geodetic system</th>
<th>Ellipsoid</th>
<th>Map projection</th>
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<td>North Cuba</td>
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<td>Trinidad and Tobago</td>
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<td>La Canoa</td>
<td>International 1924</td>
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<tr>
<td>Guyana</td>
<td>La Canoa</td>
<td>International 1924</td>
<td>UTM - zone 20 N</td>
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\( \Delta Z = -6 \)

**In Peru.** Four geodetic systems are in use. Two continental systems, plus the world system, plus a system designed by an oil company.

1-PSAD56. \( AX = -279; \Delta Y = +175; \Delta Z = -379 \)

2-SAD69. \( AX = -58; \Delta Y = +2; \Delta Z = -44 \)

3-OXY. \( AX = +341.66; \Delta Y = +308.86; \Delta Z = +55.51 \)

Like in other Andean countries in the world, most data is referenced to the PSAD56 system. An equal amount of data is expressed in the OXY system.

**In Brazil.** This country did not participate in the PSAD56 project but it did participate in the SAD69 project in which most information of petroleum interest is expressed. However, some data is referenced to the Aratú datum used by Petrobras all along the Atlantic coast.

1-SAD69. \( AX = -60; \Delta Y = 2; \Delta Z = -41 \)

2-Aratu. Shifts: \( AX = +145; \Delta Y = -296; \Delta Z = +147 \)

3-Crôrrego Alegre. Shifts: \( AX = -206; \Delta Y = 172; \Delta Z = -163 \)
The latter is in use in central-southern Brazil and the area surrounding the north-eastern coast of Brazil.

**In the Rest of the World**

From an administrative viewpoint, “Rest of the World” for RepsolYPF involves countries in Europe (Spain), Africa (Algeria, Libya, Morocco, Equatorial Guinea, Sierra Leona and Angola), in Asia (Saudi Arabia, UAE, Iran, Kazajstán and Malaysia), in North America and Central America (United States, Mexico and Cuba) and, finally, in other South American countries (Trinidad-Tobago, Guyana and Venezuela). Each country along with geodetic systems in use, associated ellipsoids, and vector data projection systems are shown in the table on the previous page. Following is an example of the situation in Spain:

**In Spain.** Most data is expressed in the old ED 1950 datum with geocentric shifts as follows:

\[ \Delta X = -84; \Delta Y = -107; \Delta Z = -120. \]

These shifts account for a planimetric shift of +111 m along the east-west axis and +204 m along the north-south axis, both with respect to the WGS84 datum.

**HYDROCARBON EXPLORATION AND GEODETIC SUPPORT**

Although no statistics are available to quantify the influence of the “geodetic error” on an unsuccessful exploratory well, it is deemed to be fairly low. However, in 1991 a case history was disclosed, which is considered symbolic these days. In Argentina, a well was drilled in the wrong exploration area and in the wrong province, owing to a combination of erroneous concepts including use of an inappropriate geodetic system. Initially, relevant maps showed that the well had been drilled in an area operated by YPF in the Province of Formosa. However, it was later found to have been drilled in the Province of Salta, which bounds the Province of Formosa on the west. Even worse, it had been drilled in an exploration area operated by another company. Surprisingly, the well proved successful so an agreement had to be reached between both companies to settle the dispute with a slip being driven into the area surrounding that in which the well had been drilled. This deal, which benefited YPF significantly, could be made because by that time YPF was the state-owned company that ruled the oil market and led the way. If this had happened these days, the well should have to be assigned with subsequent investment and profitability losses (should the well prove commercially profitable), well production would be shared, or, in the best case, a compensation or rental would be paid to keep the well.

Any geologist who has dealt with petroleum systems in Argentina’s San Jorge Basin knows that reservoirs behave as narrow channels (an average of 150 m). This means that a discrepancy of a bit more than 120 m between geodetic systems can be critical in determining the final outcome of the well drilled. Indeed, during the last five years, several dry wells were reported, which could have proved successful if the geodetic systems of geological and exploration data reviewed to propose the well had been adequately considered.

The fact that this is no longer considered as part of the exploration risk, coupled with the disclosure of case histories as those referred to above, should be emphasized. However, no systematic approach has as yet been developed by major oil companies to finally standardize a unique geodetic system on the basis of all georeferenced digital data available. It should be emphasized, however, that now they are at least aware of the scope of the problem. And with the joint effort of individual geodetic experts, the support of several geologists, and the consent of a few managers, partial improvements are being implemented.

**Inconveniences resulting from disregarding geodetic systems**

Considering the three main issues involved in hydrocarbon exploration, i.e. delimitation of the study area, seismic recording and well drilling, some of the most serious situations resulting from disregarding geodetic systems are shown below:
Wells. A well may be:
1-Erroneously drilled in a neighboring area. The well may prove productive or not, depending on matching with other data.
2-Shifted from a seismic line, which may affect reservoir extent.
2-Shifted from the reservoir, which results in the loss of money spent in drilling the well.

Areas. Area delimitation and surveying may involve:
1-Significant shifts leading to superposition with adjacent areas, which in turn may lead to legal claims on account of trespassing private property.
2-Shifts leading to a path or a strip with neighboring areas, which should in fact be adjoining areas.

Seismic. Superposed programs originating from different geodetic systems. This may result in:
1-Fictitious (non-existent) coincidences between shotpoints.
2-Unreal line crossings.
2-Line shifts resulting from use of different seismic programs, while lines should coincide at least at one crossing or one shotpoint.
Satellite images, contours, bathymetric lines, pipelines, contact lines between surface geological formations, also are critical as these elements combine and superpose for geological studies. For this reason, it is absolutely necessary to thoroughly know the geodetic system in which they were derived.

CONCLUSIONS

From their very beginning and for several decades, major state oil companies managed all the processes and services required for their activities, both primary and secondary.

Yacimientos Petrolíferos Fiscales (YPF), the old state oil company, also followed this structure pattern which was in place in the company until the early 1990s when globalization of the capitalist economy called for a thorough restructuring process designed to fit the new economic environment and thus compete more efficiently. As a result, the company was privatized to become a corporation in 1993. In addition, it underwent a reengineering process and disposed of unnecessary assets and services, which were later outsourced to improve efficiency.

However, eagerness for restructuring also led the company to dispose of a Department which would have provided highly useful services to the current RepsolYPF whose operations in 24 countries all over 4 continents have made the data coordinate system issue even more complex. This is the so-called Geodesy and Topography Department which today would be mainly involved in developing and enforcing coordinate measurement standards, monitoring contractors for compliance with such standards, supporting other company departments which call for coordinate measurements, supervising incorporation of million well coordinates and historical seismic lines into a unique geodetic system, etc. Thus, georeferenced data would become consistent and the workload of geologists, geophysicists, and other experts engaged in adding oil reserves would be reduced.

Top managers should be committed to the unification of geodetic systems and the permanent control of georeferenced digital data quality as this data is the result of most projects and studies designed to find the stock that fuels the oil business. Without this stock (hydrocarbons), there would be no business, no company, no clients, and no shareholders.

Undertaking the task of marking out the ground plan and validating historical data coordinates, improving capture of current data, and monitoring the quality of future data, is relatively easy if carried out in an orderly, methodical and systematic manner by a small team of qualified people provided with appropriate software. The monthly cost of this project would probably be less than 10% of the cost of a deep exploratory well. But cost-effectiveness would be high since millions of “junk digital data” which are currently stored in the company’s huge database could be retrieved and used.

Finally, it should be emphasized that while marking out of the ground plan of well coordinates and 2D and 3D seismic is a predominantly geological-geophysical job, area surveying concerns mainly the legal aspect. In the former case, good data quality will help adjust the required information (satellite imagery, seismic sections, structural, lithological, topographic data, etc.) more precisely for potential geological-geophysical projects and studies and eventual well proposals. As for the latter case, this will help avoid legal disputes with adjoining areas operated by other companies with surveys being based only on the official geodetic systems in use in each country concerned.
Oil companies are well aware of the geodetic problem. The required conditions already exist thanks to technological and satellite advances and qualified specialists have already gained wide experience. Now, it is only necessary to meet the challenge with top management support and commitment.

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Gabriel Oscar Álvarez was born in Buenos Aires (Argentina) on December 25, 1959.

In 1983, he graduated with honors from the Escuela de Cartografía del Servicio de Hidrografía Naval (School of Cartography of the Naval Hydrography Service, presently called School of Ocean Sciences which belongs to the Naval University Institute).


In 1984, he also collaborated with Aeromapa, a firm carrying out aerophotogrammetry, where he learned restitution of photograms by means of analogical methods, as well as how to produce urban mapping.

Towards the end of 1985 he lived for a few months in Brazil, where he learned how to speak Portuguese. He then took extra Portuguese courses and is now fluent in the language.

In 1986, he became cofounder of the Asociación Argentina de Cartografía (Argentine Cartography Association), and here he was academically active, organizing courses and conferences and publishing a newsletter. He was President of this Association many times for alternate periods.

In 1988, he started working for the Argentine state-owned oil company YPF, which in 1999 became Repsol YPF, after being acquired by, and then merged, with the Spanish oil company, Repsol. Today it is ranked as the eighth oil company in the world.

Besides carrying out his work in the oil industry, he took part in the following National Cartography Congresses: in the city of Santa Fe in 1991, in Mar del Plata in 1993, and in the city of Buenos Aires in 1995, 1997 and 2000. In 2002 in Mar del Plata during the Hydrocarbon Congress, he expounded on the work method “Unification of Geodetic Systems” which he wrote together with his colleague German Ramirez. During the 2003 Cartography Congress he presented “Last vestiges of political colonialism”. During the 2004 Cartography Congress he spoke on “Data acquisition and development of a GIS for seismic lines in Ecuador using paper format maps”. And finally, in 2004 during the Scientific Meeting of Geodesists and Geophysicists, he presented the report “Unification of the geodetic systems of georeferenced data in hydrocarbon activity”.

At the same time he periodically partakes in upgrading and postgraduate courses on GIS, satellite geodesy, physical geodesy, satellite image processing and interpretation, capture of GPS data, CAD design, etc.

He carries out his professional activity in the oil business in hydrocarbon exploration. From 1990 to 1993 he gave cartographic backing to geological commissions working in the field, and to the offices located in active basins. In 1992 he specialized in Geographic Information Systems (GIS) and in 1993 in geodetic systems. In 1994 and 1995 he was invited to give training courses to future users of GIS in the Company’s offices in Neuquén, Mendoza y Comodoro Rivadavia. Between 2000 and 2004 he collaborated with the Bolivia-Argentine North East group belonging to Latin American Exploration Management. Since 2004 he is part of the Faja Plegada Norte (Northern Fold Belt) group belonging to the ABB Management (Argentina, Brazil, Bolivia).

Since 2000 he has been giving internal speeches and conferences to geologists on geodetic systems and cartographic projections in georeferenced data management, and on the quality of digital georeferenced data.