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A Measure of Local Coherency Calculated from Wells for Data Checking and Geological Zonation

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Summary

A measure of coherency in facies between nearby wells is developed to aid in the processes of quality control of well data and geological zonation. Coherency measures the agreement between a well and its immediate neighbours based on structural markers and facies interpretations. The calculation can be done incrementally on sets of wells to identify incoherencies caused by errors in interpretation, measurement differences, data acquisition problems or actual changes caused by geological differences. Attributes may include the year a well was interpreted or included in a database, the interpreter, or what logging tool was used. An example involving the fluvial depositional environment of the lower McMurray formation is used to demonstrate how the measure of coherency can be used to detect quality issues between wells logged in different years.

Introduction

Quality control of well data can be a time-consuming processes in oilsands mine development, reservoir characterization and geomodeling studies (Theys, 1999; Deutsch, 2002). Data may be collected over many years prior to production. During this time, technologies for data acquisition change and multiple geologists and well log analysts handle the data, undoubtedly with some variation in the subjective process of interpretation. Two particular types of data that are prone to inconsistencies are structural markers and lithology indicators / facies due to the potentially subjective nature of these data types (Hein et al, 2002). When variations, inconsistencies or incoherencies can be detected during a quality control study, the database may require attention to improve the resulting geological models and engineering studies.

Variations in a database may be subtle and go unrecognized, especially when the database contains hundreds of wells and spans more than a decade of data acquisition. Such a scenario is typical of large oilsands mining projects, mature fields heading into enhanced recovery stages of production and of in-situ production of heavy oil. Subtle incoherencies may be perceived as inconsequential; however, they may have a significant impact on parameters for geomodeling, such as the variogram and local accuracy of prediction. In this work, a measure of coherency is defined to help detect wells that are inconsistent within a database. Coherency is calculated between a well and its immediate neighbors based on several parameters including the spatial position of wells, the facies interpretations along the wells, and the year the interpretation was done. The calculation is fast and automatic making it possible to detect incoherency in very large drillhole / well databases.

Incoherencies in a database are not necessarily due to variations in interpretation or differences in technology. Rather, they may be a product of the depositional environment. For example, a middle estuarine environment with sinuous channels, inclined heterolithic strata (IHS), breccias, and other complexities may appear highly incoherent due to the heterogeneity in facies (McPhee and Ranger, 1998). In this case, the measure of coherency has a secondary use, that is, to aid in the identification of geological zones based on the facies designations. Facies intervals along wells are clustered with nearby wells into geological objects, where the coherency is used as a similarity metric. Such geological zonation is important for defining local directions of continuity and for gridding.

Method

Computing the coherency of a well within a database based on spatial location and facies descriptions is accomplished with Equation 1:

Equation 1: Coherency of well A.

Parameters in Equation 1 are supplemented with Figure 1. The well in question is denoted *A* and B_i, $i = 1,\ldots,N$ is the set of wells in the local vicinity of *A* that are weighted by their distance to *A*, $\omega_{A,Bi}$. For each well B_i, the coherency is calculated based on the agreement of facies along the two wells using the max function. For each of the *n* facies samples along well *A*, a set, S_j, of facies samples along well B_i is determined based on a search angle, θ, and maximum search interval, *r*. The purpose of the search angle is to account for local stratigraphic variations in the data, that is, the facies data between wells do not have to align exactly in the horizontal plane. Weights between samples, $\lambda_{Aj,Bik}$, are calculated as the cosine of the angle of elevation between the samples, α, via Equation 2. The angle is scaled so that the weight when $\alpha = \theta/2$ is zero.

Equation 2: Angle based weights.

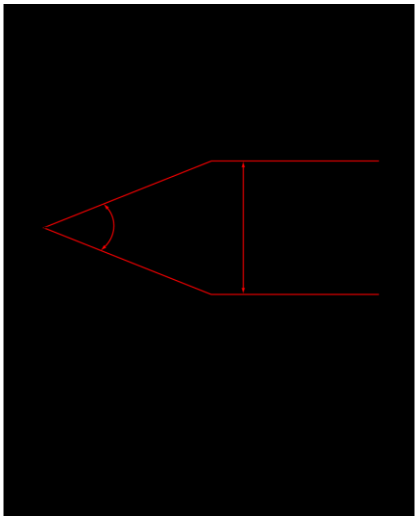

Figure 1: Parameters involved in the coherency calculation.

Lastly, $M(A_j,B_{ik})$ is a facies similarity matrix that defines how similar the facies at A_j is with the facies at B_{ik}. Along the diagonal, where $A_j = B_{ik}$, $M = 1$, that is, the facies are 100% similar. When $A \neq B$, the facies can be considered completely different with $M = 0$, or somewhat similar with $M > 0$. This makes it possible to account for facies that belong to the same type of geological entity. For example, shale and sand deposited in a laterally accreting point bar can be considered similar; otherwise the coherency may be artificially low because of the short-scale heterogeneity of such facies. This is an important parameter for using the coherency to detect geological zones. It is more reasonable to consider delineating a point bar object into a geological zone, rather than to detect the individual shale and sand drapes within the point bar. An example of a similarity matrix for a fluvial depositional environment is provided with the example in Table 1 and involves channel sands CHS, breccia BR, point bar sand PBS, point bar mud PBM, point bar mixed PBSM, and floodplain shale SH. A low similarity is set between CHS and BR because breccia tends to deposit at the base of channels, that is, it exists within the channel geological zones, but it is a substantially different facies. All point bar facies are somewhat similar because they exist in the same geological objects. There is no similarity between channel related facies and point bar facies, nor between shale and any other facies.

Example

The coherency measure is applied to a set of 232 wells that intersect the lower portion of the McMurray formation that has been interpreted as a fluvial depositional environment (Ranger and Gingras, 2003). Data was collected and interpreted over a six year time span in three periods: 2004, 2007 and 2010. Six facies are present with a similarity matrix given in Table 1. Values were determined by expert judgment.

Table 1: Similarity matrix for fluvial example.

	CHS	BR	PBS	PBM	PBSM	SH
CHS	1	0.2	0	0	0	0
BR	0.2	1	0	0	0	0
PBS	0	0	1	0.3	0.5	0
PBM	0	0	0.3	1	0.5	0
PBSM	0	0	0.5	0.5	1	0
SH	0	0	0	0	0	1

Coherency was calculated for each well using three nearest neighbors, a search angle of 3 degrees and maximum search interval of 10 meters. To identify incoherencies due to the sampling year, several executions of the coherency calculation were done including: 1 – 2004 wells only; 2 – 2007 wells only; 3 – 2010 wells only; 4 – 2004 and 2007 wells; 5 – 2007 and 2010 wells; and 6 – all years together. Incoherencies are identified by significant changes in the coherency of a well between cases. Within cases 1, 2 or 3, a low coherency may indicate facies or structural marker interpretation issues. Low coherencies may also indicate that the facies heterogeneity exists at a shorter scale than the well spacing.

For this example, the change in coherency of the 2007 wells when combined with the 2004 wells is analyzed. Figure 2 shows the wells shaded by year with those having a decrease in coherency greater than 10% highlighted. Wells 318 and 352 from 2007 show a significant reduction in coherency due to well 337 from 2004. Coherency of wells 318 and 352 from case 2 was 93.5% and 63.2% respectively. These were reduced to 79.2% and 51.7% with well 337. Using this information, the facies profile of well 337 with its three nearest neighbors was generated for further checking (Figure 3). There appears to be a significant different in the interpretation of breccia between the wells. This may warrant further review of the available data including core or core photos and petrophysical logs.

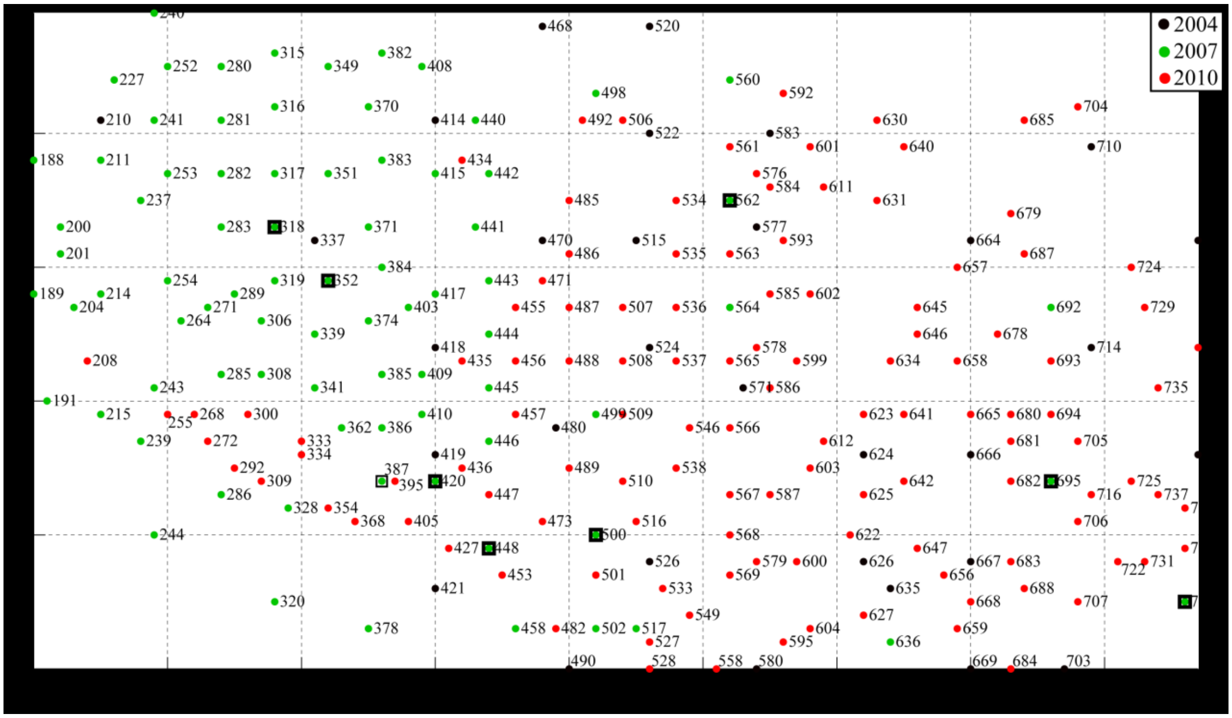

Figure 2: Wells from 2007 with a large drop in coherency due to 2004 wells.

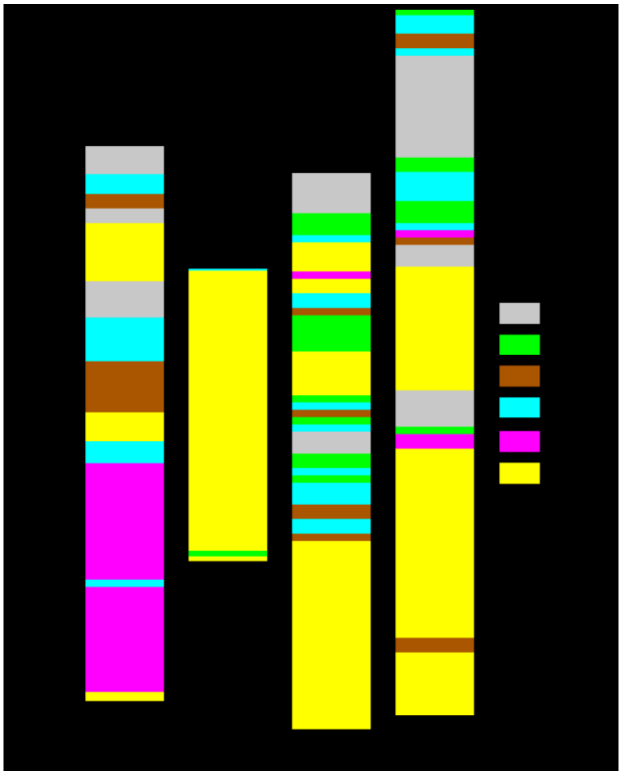

Figure 3: Facies profiles of well 337 and its 3 nearest neighboring wells.

Conclusions

The coherency measure introduced above is useful for detecting problems in drillhole / well databases including incoherencies due to the progression of sampling over time and different interpretations of the facies data and structural markers. It is also useful for detecting if the well spacing is larger than the scale of heterogeneity of the facies involved. The coherency calculation is fast and can therefore be executed on large databases and many times on different subsets of the data to aid in the detection of incoherencies with the incremental addition of wells. Although it was not shown, another use of the coherency measure is for geological zonation. Region of high coherency can be clustered together into similar geological zones, which has significant use in inference of local statistics such as the variogram and for geological gridding.

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References

Deutsch, 2002, Geostatistical reservoir modeling, Oxford University Press, 384.

Hein, F.J., Cotterill, D.K., and Berhane, H., 2000, An atlas of lithofacies of the McMurray formation, Athabasca oil sands deposit, Northeastern Alberta: surface and subsurface. Alberta Energy and Utilities Board, 217.

McPhee, D. and Ranger, M.J., 1998, The geological challenge for development of heavy crude and oil sands of Western Canada. Proceedings 14th International Conference on Heavy Crude and Tar Sands, Beijing, 1765-1777

Ranger, M.J. and Gingras, M.K., 2003, Geology of the Athabasca oil sands: field guide & overview. Ranger, M.J., and Gingras, M.K., 123.

Theys, P., 1999, Log data acquisition and quality control. Editions Technip, 453.