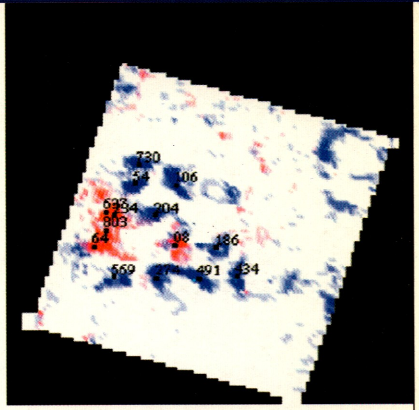
HOW TO COMBINE SEISMIC ATTRIBUTE MAPS:

APPLICATIONS IN TWO VENEZUELAN FIELDS



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A new method to combine information from various seismic attribute maps is presented. It compares the response about some points of interest with attribute response in the rest of the area studied. Method consists of three steps. First, control points are selected and grouped in different classes. Second, similarity maps related to each class are created, associated to different primary color. High similarity values observed in the maps represent areas whose attribute response is similar to response around control points. Low values indicate areas where attribute response is not similar to response around control points. Third, similarity maps are combined into one, in which different color saturation levels represent the state of each class. Colors in the final map result from primary color combination of individual similarity maps. For map interpretation, areas with similar seismic response and near control points shall be considered of having similar rock properties, assuming subsoil changes are gradual.

Se presenta un nuevo método para combinar la información contenida en varios mapas de atributos sísmicos, el cual consiste en comparar la respuesta de los atributos alrededor de ciertos puntos de interés, contra la respuesta de los atributos en el resto del área de estudio. El método se aplica en tres pasos. En el primero los puntos de interés son seleccionados y clasificados en diferentes categorías. En el segundo se crean los mapas de similitud relativos a cada categoría y a los cuales se les asocia un color primario diferente. Los valores altos de similitud que se observen en estos mapas, representan áreas cuya respuesta de los atributos es similar a la respuesta alrededor de los puntos de interés. Los valores bajos indican áreas en donde la respuesta de los atributos es poco parecida a la respuesta alrededor de los puntos de interés. En el tercer paso los mapas de similitud son combinados en uno solo, en el cual los distintos niveles de saturación de colores refieren el grado de similitud con cada categoría. Los colores en este mapa final resultan de la combinación de los colores primarios de los mapas individuales de similitud. En la interpretación de estos mapas se debe considerar que aquellas áreas con respuesta sísmica similar y cercanas a los puntos de interés, deberían tener propiedades de rocas similares asumiendo que los cambios en el subsuelo son graduales.

Interpretation of seismic attributes in terms of petrophysical properties is usually performed by exhaustively analyzing the correlations between all attributes against all petrophysical properties available in a certain area. In recent years, interpreters have started to compute as many attributes as they can from their seismic data, with the hope that some attribute will help in the extrapolation of key reservoir properties. In certain cases, the physical relation between attributes and reservoir properties can be intuitively understood but, unfortunately, this is not always the case. Furthermore, relations between seismic and petrophysics that are valid for one area may not be valid for other areas. However, even though the calculation of many "non-physical" attributes complicates their interpretation, interpreters still compute and use such attributes because they help to analyze their data in endless ways which are not necessarily redundant.

In exploratory areas, the problem of interpreting seismic attributes becomes even more difficult because of the lack of information. Unfortunately, interpreters still have to decide where to drill new wells, relying only on the little petrophysical and production information they have gathered from the few wells already drilled in the area. To add more uncertainty into the interpretation of attributes in exploratory areas, there is a high risk in such areas of finding false correlations between seismic attributes and reservoir properties, simply because the number of wells is not statistically significant to represent not even large scale variations throught the target, as stated by Kalkomey [1].

Computing different seismic attributes deals also with the difficulty of displaying them all together. Burnet and Radovich [2] proposed some display techniques for the combination of maximum three seismic instantaneous attributes.

Recently, Michelena *et al.* [3] proposed a method that help to summarize systematically the information contained in tens of attribute maps into just one map. They called this method similarity analysis, which is based on the simple concept that when waves travel in areas with similar rock properties, their behavior should also be similar. The similarity map shows the resemblance of the seismic response of regions across the whole study area with respect to a selected location in the reservoir. If changes in the reservoir are assumed to be gradual, similarity maps can be used to find areas of the reservoir whose overall rock properties are similar to the properties around a control point, a producing or dry well, for instance. A complete interpretation of the similarity maps should take into account all geological, petrophysical, and production information available.

The main limitation of the similarity analysis is that, when the number of control points is more than one, we are still left with the problem of interpreting various maps, one for every control point. This paper shows a new method to overcome this limitation by summarizing the information contained in similarity maps with respect to various control points. As we will show, this method can help to add new insights into the understanding of a given area.

We start by reviewing the basic ideas behind similarity analysis and presenting an example using this technique. Then, we present examples showing how to generate similarity maps referred to more than one point whose reservoir properties may be also different.

Similarity analysis: review

The input of the similarity analysis is a set of non-correlated and intervalic seismic attribute maps, the coordinates of the control point, and a radius of a circle around the control point where the attribute response is nearly constant. Seismic attribute maps used for the similarity analysis should be uncorrelated, to avoid introducing redundant information that could influence the results with some preferential trend. To generate a set of uncorrelated, seismic attributes, we use the method of Gram-Schmidt orthogonalization.

The process of generating the similarity maps can be divided into three steps: computation of reference values, classification, and sum. To obtain the reference values, the mean and standard deviation of the attributes in the reference zone around the calibration point must be computed. In the second step, each point on each attribute map is classified depending on whether its mean falls within a window centered in the mean plus-minus the standard deviation of the attribute in the reference zone. In other words, to classify a point, we compute the mean value of one attribute around such point in an area equal to the area of the reference zone. If the mean around that point is close to the mean of the reference zone (within the standard deviation) a high value, typically one, is assigned to that point. If not, a low value, typically zero, is assigned. The procedure is repeated for all points and all attributes as shown in Fig. 1a and 1b, and the result is a set of N binary maps, one for each attribute map. The last step is simply to add up all the binary maps (Fig. 1c). The result is the similarity map. Similar reservoir areas highlighted in the map should have high seismic similarity.

To interpret the similarity maps, it should be kept in mind that similar rocks or similar reservoir conditions produce similar seismic response that independent attributes should capture. Although the opposite may be not always true for areas far apart from the calibration point, we expect that areas close to the calibration point with similar seismic response to have similar rock properties, if we assume that changes in the reservoir are gradual. If the calibration point is a producing well, the similarity map associated with it will be a map of possible prospective areas in its vicinity. If the calibration point is a dry well, the similarity map associated with it highlights the zones with lower priority in exploratory or infill drilling programs.

Similarity analysis: example

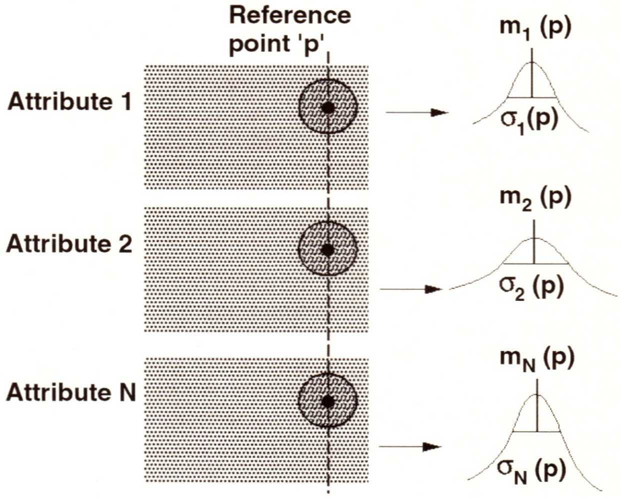

fig.1a. Mean and standard deviation for each attribute related to reference point p.

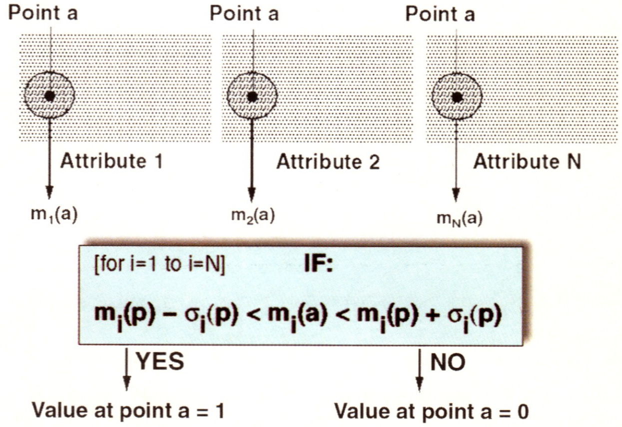

Fig. 1b. Classification of each point according to the mean and standard deviation for reference point p.

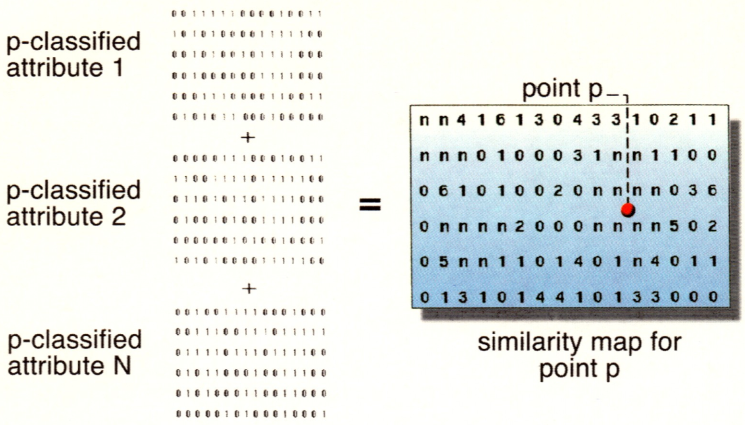

Fig. 1c. Add up all binary maps to obtain a similarity map related to point p.

zones whose seismic response does not resemble the one around the reference point.

Although the maximum number of primary colors is three, the combination of maps is not limited by this number, as long as we are able to classify the reference points in no more than three categories, for instance, wells with high oil production and little water production, wells where oil and water productions are comparable, and wells with no oil production. By using this classification, the reference associated to specific control points is lost. Nevertheles, the properties from which the categories were obtained, can still be used to characterize the reservoir.

This section shows similarity maps calculated in a oil field located in western Venezuela aimed at integrating the results of seismic attributes around productive, Cretaceous limestones. In this area, we computed a similarity map referred to the only producing well in the field, Well 1. This map summarizes the response of ten attribute maps. Well 1 has produced 0.4 *MMBO* in two years. The similarity map shows a southwest-northeast trend that was interpreted as a carbonate rim (Fig. 2). After analyzing the spatial variation of the similarity value near the producer well, a re-entry from Well 2 was proposed. This re-entry was designed as a deviated hole into the high similarity valued zone where the rock properties are probably similar to those near Well 1.

Fi. 3 shows the similarity map that results when the calibration point is one of the dry wells. Areas to be avoided in re-exploration programs are those similar to the vicinity of the dry Well 3, at least until more information is acquired, and the reservoir is better characterized.

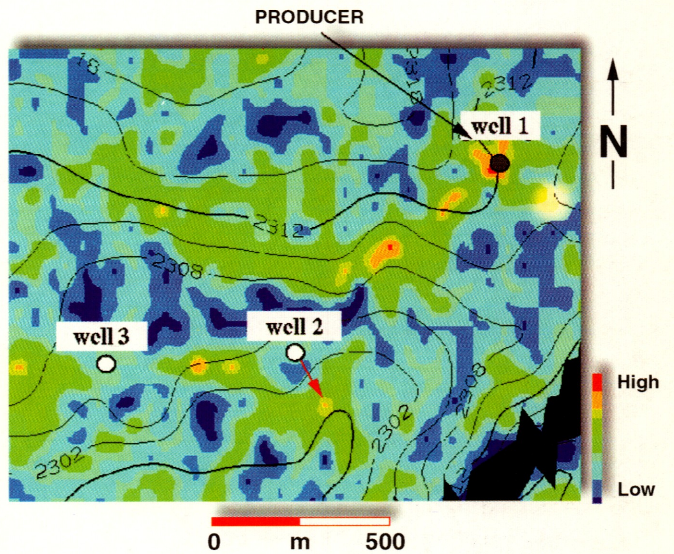

Fig. 2. Similarity map of Well 1 (producer).

Combination of similarity maps: theory

The main limitation of the similarity analysis is that each map is referred to only one point in the area of interest. When more than one point (well) is available, the method should be applied separately for each well. Therefore, the joint interpretation of the different maps related to each calibration point may not be simple. We propose in this section a new method which combines similarity maps by mixing their color saturation according to the similarity values of the calibration points previously classified.

The method starts by assigning a primary color (red, green and blue, in graphics system terms) to each similarity map computed in the area of interest. The saturation of the color for each point will be proportional to its similarity value, that is, highly saturated colored areas represent high resemblance to the reference point; lightly saturated, colored areas have the opposite meaning. White areas (a color with no saturation) indicate

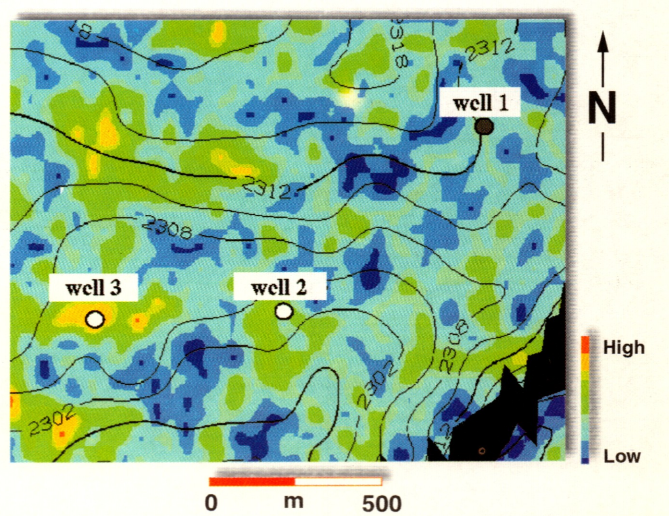

Fig. 3. Similarity map of Well 3 (dry).

After deciding which primary color will represent each category of control points, such as S1, S2, and S3, and in order to facilitate a more intuitive interpretation of the combined map, consistent with the similarity patterns of the indivual maps, the color to be computed at each point of the final map will have a color equal to one of these mutually exclusive conditions: *a)* that of category S1, *b)* that of category S2, *c)* that of category S3, *d)* the combination of categories S1 and S2, *e)* the combination of categories S1 and S3, *f)* the combination of categories S2 and S3, *g)* the combination of categories S1, S2 and S3, and *h)* white color for null values.

Due to the ambiguities that we found in the RGB color model, we adopted the HSV (Hue, Saturation, and Value) model to obtain the color saturation for each point in the combined map. This was achieved by mapping the similarity values related to the three categories, S1, S2 and S3, into the space of the HSV model.

Thus, the resultant color of each point will indicate its seismic resemblance with respect to each reference point. For instance, a dark green area in the final map indicates a zone whose seismic respond is similar to the wells that were classified and labeled with green color; lighter green areas have lower similarity with respect to such class of control points. If an area in the final map is colored by a combination of primary colors, yellow for instance, such areas exhibit a seismic response whose behavior resembles the behavior of the classes whose primary colors are use to form the resultant color in the final map, red and green color for this case.

To enhance the dynamic range of the image, so as to better identify the areas related to the different categories, we selected various non-linear transformations and applied them to the original similarity values. In this way, more appropriate color contrast were obtained for the final map.

The combination of similarity maps reduces the amount of information contained in the original attributes and similarity maps related to each control point. Fig. 4 shows how the information is treated to generate each kind of map. To generate similarity maps, we sum (vertically) classified attribute maps for every control point. The sum in the horizontal direction of the similarity maps level, represents the computation of the combined map, where control points belonging to all classes are represented.

Combination of similarity maps: examples

The first example correspond to the same area mentioned above in the section "Similarity analysis: example" (Figs. 2 and 3). Here, we computed three different similarity maps, one for each well in the field: Well 1 was considered a good producer whereas Wells 2 and 3 were dry. We assigned a different color to each map, red for the producing well, green for one of the dry wells and blue for the other one. Fig. 5 shows the result of combining these three similarity maps. Other colors besides red, green and blue are seen. They indicate that at such points the seismic response is similar to the response near to more than one reference well. Since we are combining the similarity information for one producing well and two dry wells, the combined map helps to determine the distribution of prospective and risky zones across the field.

The Fig. 5 shows a new legend that was designed to ease the interpretation of the final combined map. It helps to determine, according to the color of a given point in the map, which reference points it resembles. For the red color of the area just below Well 2, the legend indicates a similarity related to Well 1, the producing one; for the cyan area located to the left of Well 3, the legend indicates a similarity to Well 2 and Well 3, the dry ones.

The second example is about similarity maps from fourteen wells at a Eocene reservoir in Lake Maracaibo that were combined into a single one (Fig. 6). The control wells were classified according average, daily production. Similarity maps related to producing wells were combined to summarize which points have high similarity with the

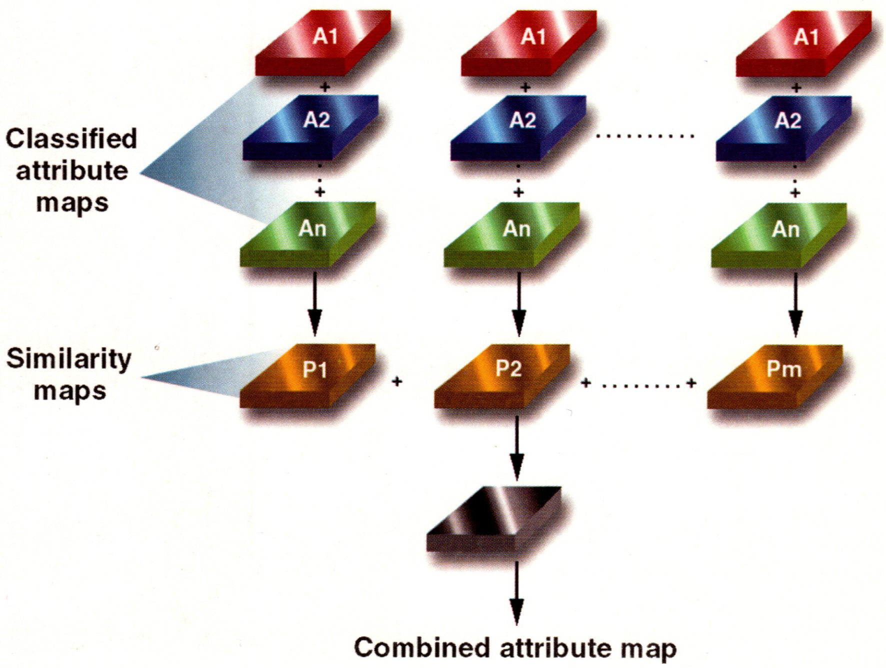

Fig. 5. Process of compilation of many seismic attribute maps.

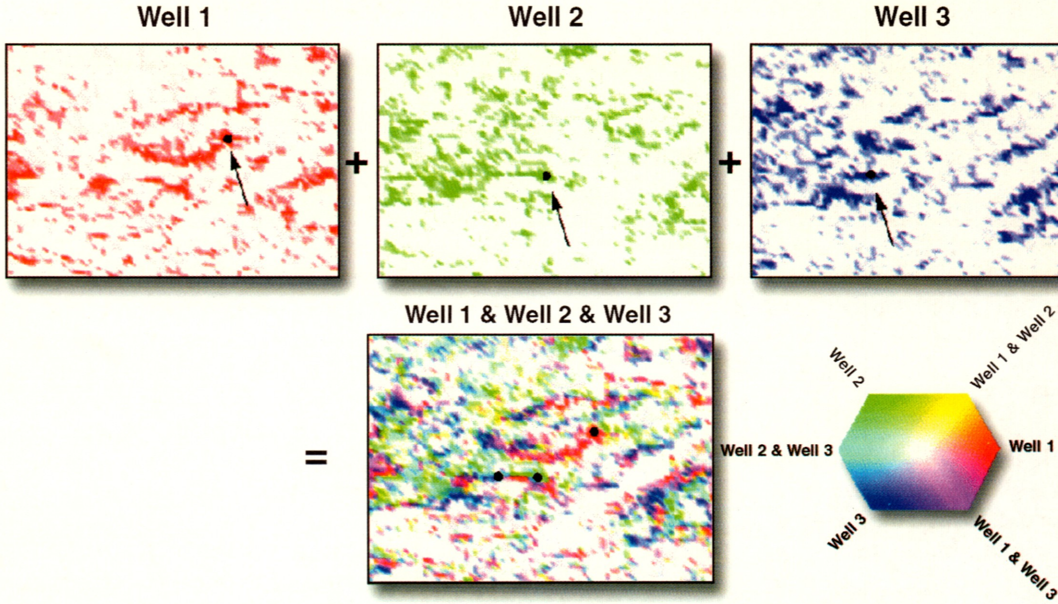

Fig. 5. Combination of three similarity maps, Barinas area. The red map is related to the producing well. The green and the blue ones are related to dry wells.

area around some producing well, indicated by dark red. Similarity maps related to dry wells were combined using blue colors. This map summarizes the information contained in 14 similarity maps calculated from 13 uncorrelated attribute maps each.

No dark magenta zones were found in the final map presented in Figure 6. These zones would indicate high seismic similarity to both areas near producing wells (in red) and areas near dry wells (in blue). This result indicates that in this field the seismic response from the areas around producing wells is clearly different to the response from areas around non producing wells.

Conclusions

We have shown a new method to summarize and interpret the information contained in seismic attribute maps that consists of three steps: classification of control points, generation of similarity maps for each class, and combination of classes. The classification should be performed according to production or petrophysical properties common to groups of wells in the study area. Once a classification criteria is selected, each class of control points is labeled with a primary color. The generation of the similarity maps shows the resemblance of the seismic response between areas around control points and other points in the study field. The combined map is obtained by finding the color saturation according to the similarity values of the categories.

The final result shows which areas of the reservoir resemble the seismic response to every class of control points, which can help identify in just one map prospective areas and areas with lower priority in exploitation programs. Similarity maps were used in this study in exploratory areas with scarce well control. More work needs to be done to understand the use of this technique in areas with more petrophysical and production information.

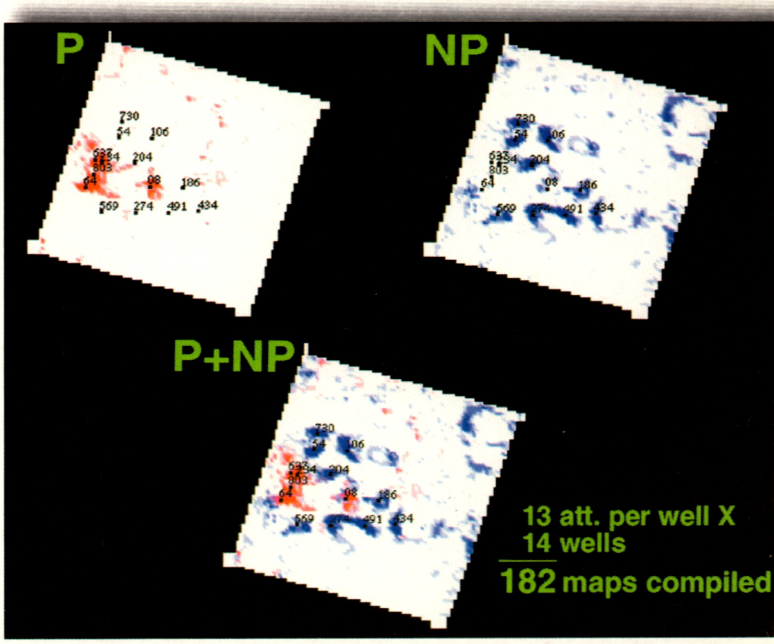

Fig. 6. Combination of fourteen similarity maps, Lake Maracaibo area. P indicates Producing wells, NP stands for Non Producing wells, and P+NP represents the combination of the Producing wells and Non Producing wells maps.

Suggestion for further reading

Capello, M.; González, E.; Michelena, R. Carbonate reservoirs and seismic attributes: How far can they go together?. *SEG Int. Exposition and 67th Annual Meeting*, 696-699, 1997.

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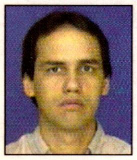

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