Automatic Detection of the Degree of Compaction in Reservoir Rocks Based on Visual Knowledge*

Carlos Eduardo Santin¹, Mara Abel², Karin Goldberg³, and Luiz Fernando De Ros³

Abstract

A low-cost method is proposed for evaluating the degree of compaction in reservoir rocks by using automatic inference methods on optical photomicrographs. In order to reproduce the visual interpretation performed during petrographic analysis, a hybrid method was developed combining image-processing algorithms with knowledge representation and reasoning models. The method proposed was inspired on visual attention, the mechanism used by the human brain for dealing with visual information. This mechanism allows the brain to filter the huge amount of information that comes through the eyes, selecting the relevant elements to be further analysed by the highly abstract level of reasoning. The process involves the decomposition of scenes, and the competition among their different aspects in order to isolate and select the relevant areas. In other words, the eyes of petrographers initially examine a thin-section by capturing and isolating the grains borders (outlines), and then focus on the grains. The outlines are essential to separate each grain from other grains and their interstices, because petrographic analysis is performed in the two-dimensional universe of thin-sections. The knowledge at this level is modelled in terms of Sections (grains), Outlines (borders of grains), and Interstices, which may be Pores (empty) or NonPores (e.g. cement, matrix). The shapes of the outlines (mainly concave or convex), complemented by the detection of the impregnation blue resin, indicates if they contain Pores, NonPores or Sections. The types of contacts between grains are then used to define the degree of compaction of the rocks. The system provides a preliminary identification of the objects that can be interactively refined by the user when the grain outlines are unclear in the images. The evaluation of compaction degree provided by this method is far more sensitive and precise than those based on the intergranular volume or number of intergranular contacts. This formalized interpretation method shows better results for the complex tasks of reservoir quality characterization and prediction.
Compaction Evaluation in Clastic Rocks

The quality of a rock as a petroleum reservoir is essentially defined by its porosity and permeability values. Basically, three diagenetic processes are responsible for the modification of the interstitial spaces during burial: mechanical compaction, chemical compaction and cementation (Fig. 1). The intensity of mechanical and chemical compaction defines the degree of proximity – or packing – of the grains, which can be termed loose, normal or tight.

Contact types approach

As the packing changes from loose to tight, the types and number of contacts between grains are modified. During progressive compaction, the dominant types of intergranular contacts shift from point (or tangential), to long (or straight), to concave-convex and to sutured (Fig. 2).

Intergranular volume approach

The degree of compaction can be estimated by comparing the present intergranular volume (IGV), quantified during the petrographic analysis, with the original IGV, measured for sediments of diverse grain size and selection. Based on these parameters, the degree of compaction is calculated considering the proportion of the original IGV of the sediments that was lost during burial. Samples with less than 50% reduction of the original intergranular volume are considered loosely-packed, while those with more than 70% of IGV reduction are considered tightly-packed, with normally-packed samples in the interval between these values.
Knowledge Modelling of Visual Aspects

In order to construct a system to process thin-section images, it is necessary a structure to represent the objects of interest in this kind of image. This structure must be machine-readable and also understandable by humans. This goal is reached by using a representation in three levels of abstraction: Image Processing Level, Visual Level, and Semantic Level (Fig. 3).

- Image processing level

At this level, the features that are machine-readable are extracted from the image. These features are related to groups of pixels. Each processed image has a real correspondence with the thin-section x-y coordinates, allowing its precise location. The spatial correspondence is controlled by an electromechanical microscope stage developed to help the quantitative Petrographic analysis through point-counting (Fig. 4).

- Visual level

The features of the objects extracted on the Image Processing Level are processed and mapped onto a higher level of representation called Visual Level. The processing of this information allows the establishment of relations among elements, such as the contact types. On this level we have concepts that are more understandable by humans (Fig. 5).

- Semantic level

The concepts of the Visual Level are mapped onto the highest level called Semantic Level, which contains the concepts related to the Petrographic domain.

By using all the representation elements (concepts, attributes, and relations) it is possible to infer the compaction degree of the rock.

System

The input in the developed system comprises the original image from the thin-section, the corresponding segmented image, and the scale for both images (Fig. 6).

Figure 6 – System inputs: A) Thin-section original image. B) Thin-section segmented image. C) The scale for the original and the segmented thin-section images.

These inputs are used by the system to extract and map the image elements for each level of representation. The system provides a preliminary identification of the objects that can be interactively refined by the user (Fig. 7).

Figure 7 – Preliminary identification of objects performed by the system. A) Incorrect object classification due to the object shape. B) System interface to refine the automatic objects identification.
The contacts among grains are manually defined (Fig. 8 and Fig. 9). An implementation to automatically detect grain contacts based on the geometry of the outlines is under development.

The representation is processed by an inference method and the compaction degree is inferred. The output is a table where both the abundance of contact types and intergranular volume are used to assess the degree of compaction, as the example below:

<table>
<thead>
<tr>
<th>Samples</th>
<th>01</th>
<th>02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punctual Contacts</td>
<td>12</td>
<td>88</td>
</tr>
<tr>
<td>Long Contacts</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Concave-Convex Contacts</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Sutured Contacts</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Output (Packing)</td>
<td>Tight</td>
<td>Loose</td>
</tr>
<tr>
<td>Input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present intergranular volume</td>
<td>4.42</td>
<td>30.69</td>
</tr>
<tr>
<td>Grain size</td>
<td>Coarse</td>
<td>Medium</td>
</tr>
<tr>
<td>Selection</td>
<td>Poor</td>
<td>Moderate</td>
</tr>
<tr>
<td>Intermediate values</td>
<td>% Lost intergranular volume</td>
<td>84.46</td>
</tr>
<tr>
<td>Output (Packing)</td>
<td>Tight</td>
<td>Loose</td>
</tr>
</tbody>
</table>

Conclusions

We propose an approach to interpret the degree of compaction of clastic petroleum reservoirs, based on photomicrographs collected during petrographic description. Since our approach is based on the shape of the contact between grains, the result is not affected by the common deformations of the image caused by optical capture. These deformations, such as the parallax that augment the area of the grains as far as are the grains from the center of the optical system, invalidate direct measures over the image.

Although the system occasionally requires human intervention in some critical steps, such as the segmentation of the images, it significantly reduces the processing time, while allowing a formalization and implementation of a very subjective method. A formalized interpretation method supports better correlation of the results along the complex tasks of characterization and prediction of the quality of petroleum reservoirs.
References


