Characterisation and quantification of reactive interface between minerals and pore space

S. Belin
L. Martinez
M. Malfroy
B. Fritz

Centre de Géochimie de la Surface, 1 rue Blessig, 67000 Strasbourg, France

Reservoir rocks consist both of a solid phase, the reactive component, and of a liquid phase, each being characterised by its own composition. The presence of a fluid within the porous network induces a chemical desequilibria which involves diagenetic reactions according to the thermodynamical conditions. These reactions result in transformations of the micro-geometry of the mineral matrix (Canals and Meunier, 1995), and thus of the physical characteristics of the porous media (Panda and Lake, 1995). Diagenetic modelling normally considers both transport and reaction kinetics but it does not take into account the physical and geometrical characteristics of the reservoir. The purpose of this paper is to examine phenomena at the pore scale by focusing on reactive interfaces, since micro-geometry and nature of pore walls are also thought to control interactions between fluids and minerals. The accurate knowledge, including nature and quantification, of the element transfer at the pore/mineral interfaces might help to determine the diagenetic processes involved and to predict the resulting modifications of the pore space micro-geometry (Carnaham, 1990 ; White and Peterson, 1990).

From a methodological point of view, this paper presents a new analytical procedure allowing both the quantification of components and interfaces. The procedure has been applied to samples from a North Sea sandstone reservoir displaying several types of diagenetic features.

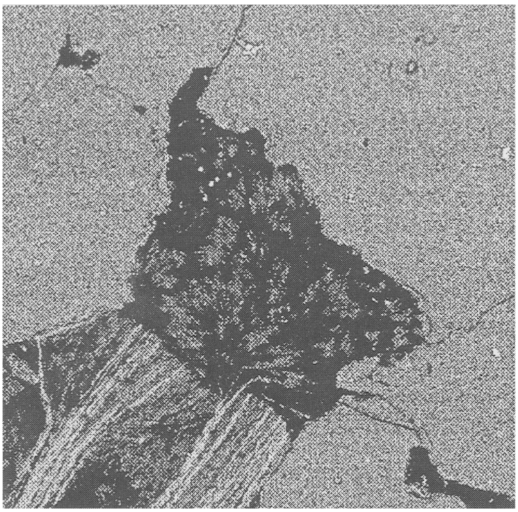

FIG. 1. Backscattered electron image (× 250) of a pore containing booklets of kaolinite being epigenised with fibrous illite.

Sampling

Samples come from the Brent sandstone reservoir of the Alwyn area, North Sea. They consist of a subarkose. They have undergone intense diagenesis which led to feldspar dissolution, silica cementation, and precipitation of kaolinite and illite.

Analytical procedure

Samples were prepared as non covered thin sections and observed with a scanning electron microscope (SEM). The analytical procedure involves two steps: (i) the acquisition of SEM images of pores displaying diagenetic products and (ii) the subsequent quantification of the components and interfaces by image analysis. Three types of images were digitised as a 256 × 256 pixels grid: (i) backscattered electron images based upon atomic number contrasts between constituents of the sample surface are used to discern porosity (Fig. 1); (ii) cathodoluminescence images resulting from defaults and impurities in the mineral lattice, and making it possible to distinguish detrital and diagenetic silica phases (Evans *et al.*, 1994); (iii) X-ray images, providing elemental maps. The elements analysed in this study are: Si, Al, K, Ca. The magnification used is × 250, which allows the best fit between the size of the pixel, the number of pixels, and the size of the X-ray beam.

TABLE 1. Proportions of constituents and interfaces present in Fig. 1

Constituents	Proportion	Specific surface
Quartz	38.6	0.0544
Diagenetic silica	21.9	0.0237
Illite	16.1	0.3441
Kaolinite	6.75	0.4874
Porosity	7.42	0.5836
TotaL	90.77	
Porosity/quartz interf.	1.29	
Porosity/illite interf.	2.58	
Porosity/kaolinite interf.	0.46	
Quartz/illite interf.	0.21	
Quartz/kaolinite interf.	0.08	
Illite/kaolinite interf.	2.75	
Quartz/diag. silica interf.	0.52	
Total	7.89	

Noise is removed from images by classical procedures used in digital image analysis. A binary image of each constituent (Fig. 2A) is made, and a colour is attributed to it. Constituents are obtained by combining the different SEM images using a computer program that has been especially designed for this purpose (at our institute). Quartz is obtained from the backscattered electron image, diagenetic silica from the cathodoluminescence image, illite from the K map, kaolinite from the Al map, and feldspar from the Al, K and Ca maps. Interfaces (Fig. 2B) are detected by displacing a cross-shaped structural element on each line of the image. Then, the specific surface value, which is the surface/volume ratio, is calculated.

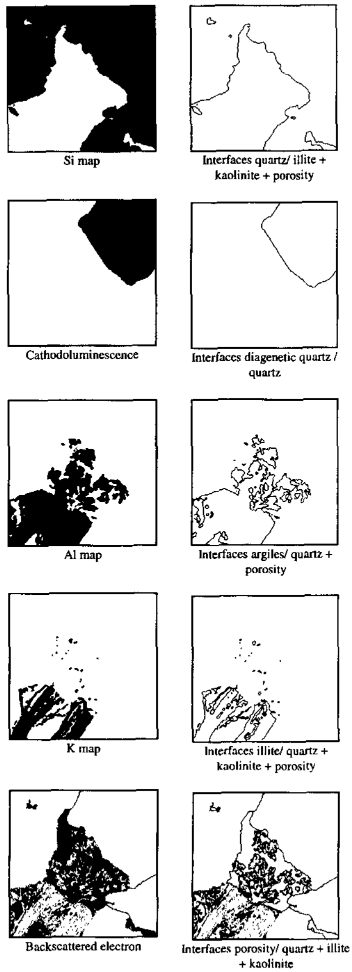

FIG. 2. (A, left; B, right) Binary images of the view of the Fig. 1 and associated interfaces.

Results

All the constituents and all the interfaces are quantified according to their nature (Table 1). As illustrated by the pore of Fig. 1, a constituent may have just one type of interface (e. g. diagenetic silica with quartz) or several ones (e.g. illite with porosity, kaolinite, quartz). The specific surface can be related to the mineral surface available for the diagenetic reactions. Both kaolinite and illite have high specific surface values which are one order of magnitude higher than the specific surface of quartz (Table 1).

Discussion and conclusion

Usual modelling of the reduction of porosity due to diagenetic processes (essentially quartz cementation) uses a simplified representation of the pore space by assuming: (i) that minerals of the matrix are represented by spheres; (ii) that the reactive surface is the surface of the spheres; (iii) that precipitations are uniformly distributed on the pore walls. With ongoing diagenetic reactions, the reactive surface changes. Digital image analysis as applied in this paper can supply important information in this respect which may be used to improve usual modelling techniques. It allows: (i) to take into account the nature of the constituents of the pore; (ii) to consider the influence of dissolutions and precipitations on tortuosity; (iii) to explicit the modification of the micro-geometry in the transport-reaction equations.