Hydrochemical Signature of Formation Waters Associated to Unconventional Gas Resources. Application to Central Coal Basin (Spain)

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Abstract

The concept of hydrochemical signature is applied to the research of unconventional gas resources (coalbed methane) in the Asturian Central Coal Basin, in northern Spain. The geochemical processes inherent to the forming conditions of coalbed methane deposits (CBM) tend to modify the quality of groundwater, then, formation water associated to coalbed methane deposits can be easily recognizable by its ”hydrochemical signature”.

The knowledge of this standard geochemical signature should have a primary use in the exploration of coalbed methane, as well as in the phases of essay and development. The hydrochemical signature of groundwater associated to the coalbed methane extraction processes can be a useful criterion in a preliminary evaluation of the interest of the unconventional gas deposits when there are enough data.

Key words: Coalbed methane, coal mining, Groundwater, Hydrochemical signature

Introduction

In a general sense, the calcium, magnesium, sodium, bicarbonate, chlorine and sulphate ionic concentrations in groundwater of a coal basin reflect the different processes of water recharge, flow, rewashing and water discharge occurred in this basin.

Waters associated to unconventional gas resources such as coalbed methane have been geochemical modified by processes of sulphate reduction, bicarbonates enrichment and sodium and chlorine contents, where they are affected by marine association waters. In these conditions groundwater is usually characterized not by their dissolved constituents but by the specific absence of some of their usual constituents.

The objective of this paper is to establish the hydrologic environment of the Carboniferous from the Asturias Central Basin Unit for a later evaluation of the role placed by the hydrogeology in the exploitability of methane adsorbed in coal beds (CBM).

Geology of Asturian Central Coal Basin

The Asturian Central Coal Basin is a fore-deep basin with many similarities to the Appalachian basin in the U.S.A. It is enclosed in the Iberian Massif, inside the unit named Cantabrian Zone (figure 1). The stratigraphic column of the Asturian Central Coal Basin has been traditionally divided into unproductive and productive Carboniferous. Traditionally, the different groups of coal beds and enclosing rocks have been subdivided into an ensemble of litostratigraphic associations which have been named “mining packets”.

The unproductive Carboniferous (Lena Group) is characterized by a great abundance of calcareous materials and for the scarce presence of coal beds. Estimated thickness is 3,500 metres and it is formed by alternations of sandstones, limolites and lutites with intercalations of coal beds, some of them sporadically exploited.

The lowest part of the Lena Group (figure 2) is constituted by a slaty level which laterally replaces the Mountain Limestone, named “Fresnedo Packet”. Immediately after are situated the Levinco, Llanón and Tendeyon Packets. This Group contains abundant calcareous levels which are rich in faune, furthermore of algae which have a scarce interest from a chronostratigraphic point of view. These calcareous levels decrease in thickness according as they approach to the hanging wall. This fact is indicative of a transit to sedimentary conditions increasingly more superficial.The productive Carboniferous or “Sama Group” contains two great coastal ensembles of 3,000 m thickness each one, over an extension bigger than 1500 km2. It is formed by alternations of sandstones, limolites and lutites, together with a great number of coal beds which have been exploited since the 18th century. Limestone is very scarce and its presence in the stratigraphic sequence is usually in the form of levels

of reduced thickness. Two great conglomeratic ensembles stand up in the middle part of the stratigraphic sequence.

Figure 1 *Geographical location of Central Coal Basin of Asturias in Spain.*

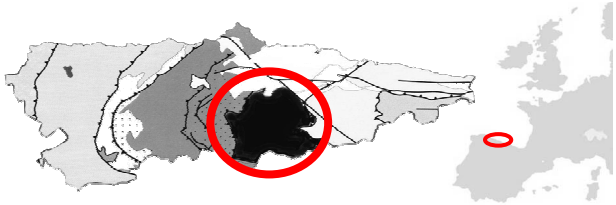
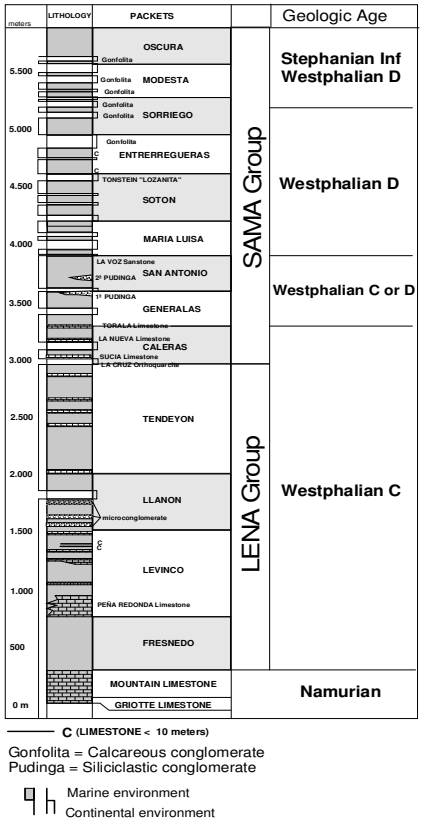


Figure 2 *Stratigraphic column of Central Coal Basin.*



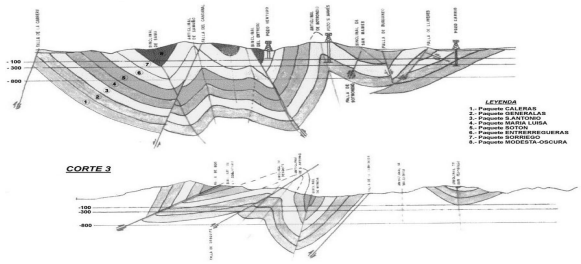
The different stratigraphic formations (mining packets) of the productive carboniferous are: Caleras, Generalas, San Antonio, María Luisa, Sotón, Entrerregueras, Sorriego and Modesta-Oscura and their age is mainly comprised between Namurian and Westphalian D. Amongst them the María Luisa and Sotón packages present the biggest density of coal beds, with an average thickness between 1 and 1.5 metres. They are sediments of plain, deltaic front and off-shore with vertical pilling of para-sequences of marine levels, coastal levels with planar, festooned and hummocky stratification and continental levels with coal beds, which correspond to successive elevations of the sea level. The coal bed thickness ranges from 0.8 to 1.5 metres.

The structural arrangement (figure 3) of the carboniferous materials corresponds with a great basin formed during the Hercynian orogeny. From a tectonic point of view three units separated by important structural accidents can be differentiated. From west to east they are: Riosa-Olloniego Unit, La Justa-Aramil Unit and Caudal-Nalón Unit. The tectonic accidents dividing these units are La Peña and La Carrera faults (Julivert et al, 1972).

The central coal basin in the north is covered by Permo-Mesozoic and Tertiary sediments. To the southern the coal basin limits with another great important tectonic accident: the León fault. To the west, the limit is constituted by the basal overthrust of the Aramo Unit pertaining to the Región de Pliegues y Mantos. To the east overlaps over the Región del Manto del Ponga, where the base is

constituted by the overthrust named “Escama de Laviana”. Structurally, it is about a basin intensively deformed and fractured and affected by two generations or folding phases, which originate great synclines and anticlines forming a typical structure of domes and basins. At a time there are faults of great sizes.

Figure 3 *General cross sections in Asturias coal basin.*



Hydrogeology of Asturian Central Coal Basin

It can be considered two main areas in a big hydrogeological basin: the Nalón and Caudal areas. From a hydrogelogical point of view it can be considered an aquifer model of multibed type, where the materials forming the stratigraphic series are characterized by a very low porosity and permeability. Porosity and permeability are very low even in the sandstone levels. The primary permeability of the not fractured rock massif is very low; it is estimated to be lower than 10-7 m/sec. In conditions of fractured rock massif the permeability is included into the interval 5•10-6 to 1•10-6 m/sec. The functioning of the multibed aquifer system is deeply altered by the mine works. Central Coal Basin is characterised by important rates of pluviometry and infiltration. Furthermore the fracturation associated to mining operations gives that in the environment of the mines the rocky massif drains in a great part towards the inside of the mine voids. The aquifers of interest are: the Mountain limestone with 200 to 300 metres thick. They are mudstone of low porosity and permeability, which acquire more favourable conditions by dolomitization, fracturation and karstification. The aquifer recharge has place in the eastern border of the aquifer and there are two types of water circulation, one of them superficial from the watershed of the Nalón and Aller riverbeds, and another one deep with unloading by diffuse circulation through the carboniferous series.

Methods

The chemical similarities of groundwater associated to the exploitation of coalbed methane deposits in different areas of the world show a chemical standard that can be used in future exploration phases for coalbed methane deposits, without taking into account lithological and/or chronological factors (Clayton et al, 1998). In those basins where the water flow conditions are well know, the concentrations in sodium and chlorine are usually lower in the areas of water recharge than in the areas of water discharge, whereas the concentrations in calcium and magnesium are higher in the areas of water recharge.

To have hydrochemical data related to deep areas of exploited coal mines will be very useful in the future for a better selection in the design and length of the pumping essays, and also in the selection of the consequent location of exploitation drills. With these purposes a water sampling campaign has been made in the deepest zones of the coal mines in Central Coal Basin. It is about waters of from medium to high mineralization (table 1), where the Na ion is in a general sense a predominant ion (figure 4). While some waters are clearly carbonic others tend to a sulphate facies.

Table 1 *Analysis of water samples collected in the deepest zone of the coal mines in Asturias Central Coal Basin.*

SAMPLE CODE	Cond	PH	Na	K	Ca	Mg	F	Cl	NO3	SO4	HCO3	CO3
B	*4420*	*8,34*	*883,5*	*6,3*	*10,8*	*23,1*	*1,3*	*17,2*	*5,4*	*698,2*	*1547,0*	*49*
H	*1945*	*7,56*	*226,0*	*7,5*	*102,4*	*75,4*	*0,3*	*11,0*	*0,0*	*330,8*	*851,6*	*0*
D	*856*	*8,38*	*201,5*	*1,8*	*4,4*	*0,6*	*1,1*	*3,6*	*4,8*	*3,4*	*530,7*	*13*
F	*1890*	*8,14*	*471,7*	*1,9*	*2,6*	*1,4*	*3,4*	*14,2*	*5,4*	*13,5*	*1174,9*	*0*
A	*750*	*7,64*	*109,6*	*4,2*	*38,3*	*16,0*	*0,2*	*9,1*	*0,9*	*66,0*	*385,5*	*0*
J	*5480*	*8,10*	*1069,1*	*10,2*	*19,9*	*9,7*	*2,5*	*92,4*	*71,4*	*1418,0*	*1087,0*	*0*

Results and Discussion

The hydrochemical analyses of water samples from the different coal mines are represented in figure 5 by means of a Schoeller diagram (Van Voast, 2003). The Schoeller diagram allows quantitative as well as comparative perspectives, both judged useful for this topic. These data allow determining the zones where the hydrochemical signature of groundwater permits to establish relations between water types and CBM deposits.

Figure 4 *Piper diagram*

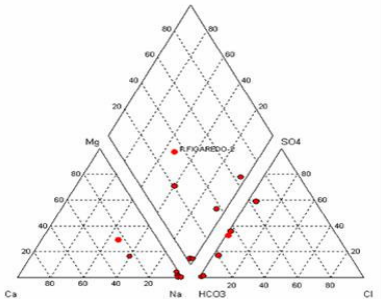
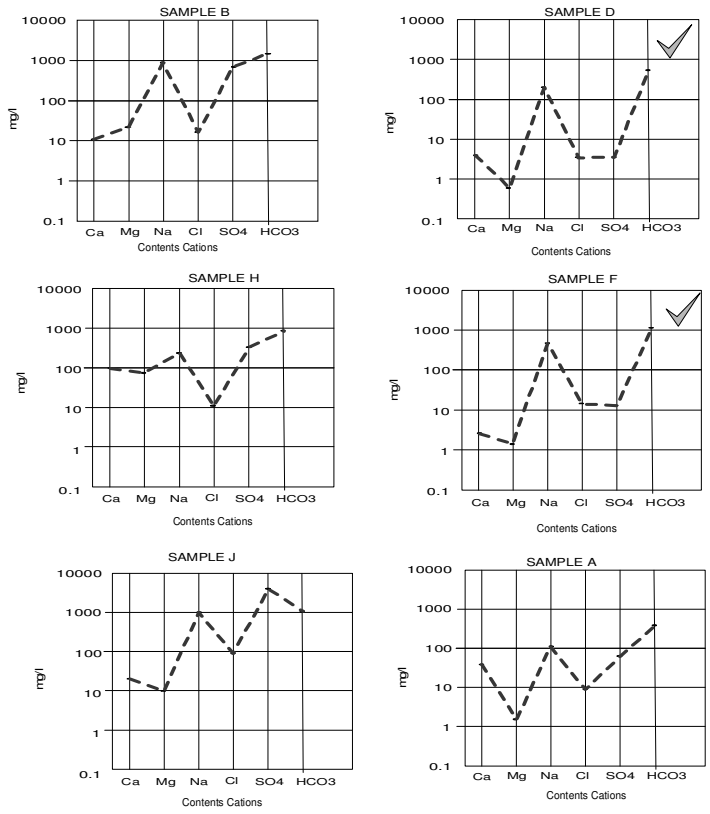


Figure 5 *Schoeller diagrams of chemical quality judget typical for coalbed-methane production waters (sample D and F) and for coalbed waters not associated with methane production (B, H, J, A).*



Conclusions

The geochemical processes inherent to methane generation conditions modify the groundwater quality to an easy recognisable water type. Waters associated to coalbed methane (CBM), have been geochemically modified by sulphate reduction processes, bicarbonates, calcium and magnesium enrichment.

References

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