Reconstruction of hydrocarbon-bearing paleofluid migration in the basement of the Great Hungarian Plain, in the area of the Szeghalom dome

1. Preliminaries, the aims of the dissertation

The SE sector of the Pannonian basin is taken up by the Békés basin (Bb), which is surrounded by metamorphic basement highs. The Bb is filled by at places more than 6000 m thick sediments, which began to form during the multiphase subsidence of the lower Miocene (ROYDEN, 1988; TARI ET AL., 1999).

One of the largest fractured basement reservoirs on the northern margin of the Bb is the Szeghalom dome (SzD), which consists of medium- to high-grade metamorphic rocks, essentially gneiss and amphibolite. These metamorhic rocks exhibit a complicated metamorphic evolution (M. TÓTH ET AL., 2000).

Due to the multiphase subsidence of the Pannonian Basin, the SzD shows a rather complex Neogene and younger structural evolution history (TARI ET AL., 1992; D. LŐRINCZ, 1996; ALBU AND PÁPA, 1999). As a result of the pre-Badenian exhumation, the SzD was affected by subsequent brittle deformation events producing a dominantly steeply dipping conjugated fault system. Based on stratigraphic, stable isotope chemical and palynological observations JUHÁSZ ET AL. (2002) constructed a model of the Neogene exhumation history of the SzD. In the well-developed sub-vertical fracture system, as the first cement phase of considerable amount, a free-standing, hydrocarbon-inclusion bearing quartz phase appeared.

With my tutor, Tivadar M. Tóth we chose this quartz phase as the object of the dissertation. I aimed to determine the wells of the SzD containing HC-bearing quartz crystals and to specify the formation conditions of the quartz precipitation. Based complementary analytical methods I tried to classify the spatial relationships of the similar or different hydrocarbon fluid types.

2. Analytical methods

To determine the appearance of the fracture filling quartz phase I have studied all the available bore cores reached the metamorphic basement on the SzD.

The thin- and thick sections were made on the Department of Mineralogy, Geochemistry and Petrology of the University of Szeged and in the Institute of Mineralogy and Petrology of the Montanuniversität Leoben.

Due to their frequency in the upper crust and the stable crystal structure, the quartz is the most useful mineral for reservation and investigation of fluid-inclusions (SHEPHERD ET AL., 1985).

The simultaneous trapping of co-genetic HC-bearing and aqueous (primary) fluid inclusions the homogenization temperature of the later type can be used as a rather precise geothermometer regarding the temperature of the formation of the host mineral (MUNZ, 2001). In order to determine the temperature of the quartz precipitation I have searched for co-genetic aqueous fluid incluison assemblages.

To specify the qualitative/pseudoqualitative composition of the HC-bearing fluid inclusions after the petrographical description I have investigated the samples by indirect (2.1.) and direct (2.2.) analytical methods.

In order to separate the HCL-bearing fluid inclusion assemblages in the successive growth zones I performed their UV fluorescent spectra and compared the derived spectral parameters (HAGEMANN AND HOLLERBACH, 1985; STASIUK AND SNOWDON, 1997).

2.1. Indirect methods

During the indirect analysis I tried to get information about the conditions of the quartz precipitation and about the composition of the trapped fluid. I applied the following indirect methods:

- microthermometry
- Raman microspectrometry
- UV fluorescent microspectrometry
- ^{1}H MAS NMR microspectrometry

2.2. Direct analytical methods

Prior to the direct analysis the opening of the fluid inclusions should be done to liberate the rather small amount (μL) of the trapped fluid. I have performed this by thermal decrepitation of the samples. The disadvantage of this method is the possible degradation of the hydrocarbon components. A further difficulty can be resulted during this type of opening the mixing of the liberated fluids from the different fluid inclusion assemblages. In order to avoid this mixing effect the crystals were heated with a stable 10 K/s velocity and the mass spectra were detected at every 500 milliseconds. Simultaneously, the continuous total ion current was recorded too in order to trace the decrepitation temperature of the inclusions. Using this method I was able to determine the composition of a given inclusion in the moment of the decrepitation.

During the preparation of the dissertation I used the following direct analytical methods:

- gas chromatorgaphy
- mass sepctrometry

3. New scientific results

1. I found free-standing quartz crystals appearing in the cracks of the metamorphic rock of the SzD in 12 wells (Szeghalom (Sz)-Nyugat-3, Sz-Észak-2 and -11, Sz-2, -11, -12, -20, -43, -110, -167, -176, -180 wells). The veins show a steep dip in each case (70-90°).
2. Based on the observed mezo- and microstructures, the wells located in the northern foreground of the SzD (Sz-É-2 and -11) explore a ductile shear zone, which developed in the rocks of the "Déva orthogneiss" described by M. TÓTH & ZACHAR (2003). The decreasing grain size to the depth, the characteristic asymmetric microstructures (mantled porphyroclasts, mica fishes) and the well-developed extensional crenulation cleavage suggest the operation of a mylonitic zone. The secondary, aqueous fluid inclusions of the calcite phase following the idiomorphic quartz with a homogenization temperature above 200 °C as well as the absence of the HCL-bearing fluid inclusions suggest different formation conditions compared to the central part of the SzD. Based on these observations, the northern foreground of the SzD was not affected by the (HCL-bearing) quartz cementation.
3. A fracture filling mineral sequence of the Sz-Ny-3 well is similar to those of the central part of the SzD described by a JUHÁSZ ET AL. (2002). According to

the several growth zones observed, a multiphase quartz precipitation occurred. The primary and pseudosecondary fluid incluison assemblages contain an dominantly aqueous liquid and a methane saturated vapour phase. The quartz precipitation (~ 130 °C) happened at a temperature similar to the other wells of the SzD but liquid HC traces are not known in this well. The fluid inclusions of the subsequent (second) carbonate phase (calciteII) refer to a "high" temperature carbonate cementation event (T_{hom}=74-106 °C), which was not known from the central part of the SzD so far. Consequently, the fracture filling mineral phase of the Sz-Ny-3 well is different from those studied in the central part of the SzD.

The HC_L-bearing quartz crystals of the SzD (expect the Sz-43 and 110 wells) trapped primary oil and aqueous fluid inclusions along several growth zones. The size and frequency of the aqueous inclusions is much smaller than the HC_L-bearing ones, while their distribution is rather unequal, that makes the comparison of the temperature of the quartz precipitation very difficult. Based on the microthermometry of the aqueous inclusions co-genetic with the HC_L ones, precipitation of the quartz phase happened at ~130 °C in the central part of the SzD.

The quartz crystals of Sz-11 and 167 wells differ in habit and colour from those of the southern wells. According to the UV fluorescent properties the HC_L fluid inclusions of the Sz-11 well contain an organic fluid, which is unique through its unmaturity/high grade degradation. These oil inclusions occur along parallel growth zones. The fluid of the youngest (secondary) inclusion assemblage represents the most mature/least degraded hydrocarbon type in the well. The oil inclusions of the different growth zones in the Sz-167 well are similar. The HCL show higher maturity/less degradation relative to the fluid of the Sz-11 well.

6. In 5 wells located in the centre of the basement high I described a fluid types characterised by varying V/L values, colourless liquid and vapour phase occurring as primary fluid inclusions (*Type 180*). This fluid type in the Sz-2, 12 and 176 wells appears in a well-defined fluid sequence, during the late stage of the quartz cementation, whereas in the crystals of the Sz-20 and 180 wells only this fluid type is present. Simultaneously with the appearance of the *Type 180* fluid a salinity drop can observed (6,3→1,2 wt% $NaCl_{eq.}$) in the aqueous inclusions. Based on the low temperature partial homogenization ($L_1+L_2+V \rightarrow L+V$), the low intensity, bluish fluorescence emission as well as the results of the Raman and ^{1}H-MAS-NMR spectroscopy, the *Type 180* fluid is of condensate type. The varying V/L ratios suggest a near critical state trapping.
7. The inner growth zones of the crystals of the Sz-2, 12 and 176 wells contain a brown colour liquid phase, which show similar fluorescene properties in each 3 wells. The maturity/degradation grade of this fluid type is between the *Type 180* and the fluids of the Sz-11 and 167 wells.
8. Based on the ^{1}H MAS NMR spectroscopy, the mean CH_2/CH_3 ratio and the methane content fall in the samples of the Sz-2 well between those values of the Sz-167 and 180 wells. The verification of the possible mixing of the 2 later fluid types "in the Sz-2" needs further investigations.
9. By means of the homogenization and final ice meltig temperatures of the aqueous inclusions as well as the UV fluorescence properties of the co-genetic HCL-bearing inclusions, I have modified the fluid migration model constructed by JUHÁSZ ET AL. (2002).

10. I have managed to separate zones of different HCL-bearing fluid regimes in the central part of the SzD.

Possible applications of the results

Free oil, having the same source rock as the hydrocarbon-bearing fluid trapped in the quartz crystals has not been mentioned from the SzD yet. The reason of this anonymity can be the very low quantity of the formed fluid, or its entire degradation except the small traces preserved in fluid inclusions. It however cannot be ruled out either that the live oil of this type accumulated in that part of the fractured metamorphic basement, which has not been taken into consideration during the hydrocarbon exploration, yet.

The methods described in the dissertation can be used besides the exploration of the fractured reservoirs also during the investigations of the cement phases of different sedimentary rocks and reservoirs, as well. Considerable amount of the produced oil in the SE sector of the Pannonian basin originates from sedimentary reservoirs, mainly sandstones, which is the best sedimentary candidate for fluid inclusion investigations. By means of the cement hosted hydrocarbon inclusions the formation conditions of the diagenesis and the comparison between the former oils and the produced hydrocarbons would be realistic (BLANCHET ET AL., 2001).