Fluid Flow and Sealing Properties Associated with an Active Faults – Kura Basin, Azerbaijan

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Fluid Flow and Sealing Properties Associated with an Active Faults - Kura Basin, Azerbaijan

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SUMMARY

With the advent of stereoscopic data such as as Landsat and SPOT imagery, these methods have been applied to satellite data and used to successfully obtain quantitative measurements over large areas. On this connection, these methods have assisted considerably in fault analysis considerations and detection hydrocarbon seeps in surface of the Kura basin which are considered main oil and gas bearing region in onshore Azerbaijan. The satellite imagery interpretation drew upon knowledge of structural geology and geomorphology and detected hydrocarbon seeps related to fault and mud volcano geomorphology. The main objectives are to determine the role of faults and mud volcanoes within the geologic structure of the study regions and to guide future oil exploration. Remote sensing to detect hydrocarbon seepage onshore allowed recognition of marginal and sub-marginal low-relief structural prospects and stratigraphic traps that is overlooked by reflection seismic surveys. Remote sensing data and images were integrated in hydrocarbon exploration programs with other exploration data such as seismic surveys, well logs, gravity surveys, and other geologic-geophysical investigations. Analysis of satellite data allowed to determine the geometry of the fault system and around them distributions of hydrocarbon seeps and to predict hydrocarbon potential of the Kura basin.

INTRODUCTION

In sedimentary basins faults play an important role in creating hydrocarbon traps. For a better appreciation of the risk associated fault-controlled prospects of the production from faulted fields, it is important to understand the processes that contribute to fault seals. In this connection, Kura Basin has specific geologic settings about fault cutting a reservoir sequence. This region is considered a classical region for development of mud volcanoes because the largest collection of those features is concentrated here. The majority of these mud volcanoes are connected with hydrocarbon seeps. Structural geologic conditions of this area are characterized by stratigraphic breaks with large dislocations, compression, thrusting, and other features. At the same time geologically, high rates of sedimentation occurred in this area. These processes produced sizeable thickness and accumulation of plastic clays of Paleogene-Miocene and Pliocene-Quaternary deposits accompanied by widespread development of diapirs and mud volcanism. Oil and gas content of this region coincided with strong tectonic dislocations and complicated faulting of structures. Because, prediction the sealing properties of the fault system and fluid flow occurrence in the Kura Basin has great significance.

METHODS

The identification of prospective structures for hydrocarbon exploration and production involves the integration of surface and subsurface data. Although good surface maps are available for many previously explored region, surface maps for remote and unexplored areas are commonly poor to nonexistent. The first step in exploring such areas commonly involves the delineation of prospective structures using surface mapping. Remote-sensing techniques have long been recognized as an effective tool for supplementing direct field measurements in structural mapping. These methods allow rapid mapping of areas and are most effective in areas where structures are poorly exposed or inaccessible. Traditional approaches included the use of areal photographs and satellite and radar images to map formation contacts and faults (Sabins, 1997). With the advent of stereoscopic data such as Landsat and SPOT imagery, these methods have been applied to satellite data and used to successfully obtain quantitative measurements over large areas. On this connection, these methods have assisted considerably in fault analysis considerations and detection hydrocarbon seeps in surface of the Kura basin which are considered main oil and gas bearing region in onshore Azerbaijan. The satellite imagery interpretation drew upon knowledge of structural geology and geomorphology and detected hydrocarbon seeps related to fault and mud volcano geomorphology (fig.1). The main objectives are to determine the role of faults and mud volcanoes within the geologic structure of the study regions and to guide future oil exploration.

Remote sensing to detect hydrocarbon seepage onshore allows recognition of marginal and sub-marginal low-relief structural prospects and stratigraphic traps that is overlooked by reflection seismic surveys. Remote sensing data and images are integrated in hydrocarbon exploration programs with other exploration data such as seismic surveys, well logs, gravity surveys, and other geologic-geophysical investigations. As a regional studying methodology, remote sensing data were made more precise by above-mentioned investigations (Tharsher and etc., 1996). Many researchers also have attempted to use remote sensing imagery to detect distinct spectral characteristics of surface manifestations of hydrocarbon seepages originating from oil and gas reservoirs at depth. The occurrences of surface hydrocarbon seeps indicate that oil or gas reservoirs are leaking even though they act as traps for hydrocarbons (Halbouty, 1980 & Zeinalov, 2000).

Figure 2 is an illustration of the association between hydrocarbon accumulations and regional faults in the western flank of the Kura Basin, because majority distribution of mud volcanoes located here. Based upon this information and additional geologic-geophysical and remote sensing research,

a faults map has been derived. The map shows many faults with different orientations and styles of movement (sub-latitudinal, caucasusian, anti-caucasusian, sub-meridional, etc.) and depth of occurrence (from pre-Mesozoic up through younger Cenozoic ages) with their associations with hydrocarbon seeps and mud volcanoes. These interpretation results were used for estimation of fault sealing and hydrocarbon occurrence in the Kura Basin.

RESULTS AND DISCUSSION

Geological factors driving both mud volcanism and hydrocarbon seeps in Azerbaijan are coeval with compressional tectonic stress, rapid Paleogene through Quaternary sedimentation (more than 6 km of sediment), and resulting abnormal pore pressures in both reservoir and non-reservoir rocks. Under these conditions, petroleum accumulations and preservation in the subsurface are relatively remarkable.

Most seepage occurs in faulted areas in the onshore part of Azerbaijan. From satellite image analysis, fault system geometry was determined and allows us to predict likely vertical oil migration from source rocks to tectonic traps and volumes of oil reservoirs in the overlying formations. Surface oil and gas seeps primarily reflect avenues of migration (or escape) from deeper and sometimes distant locations.

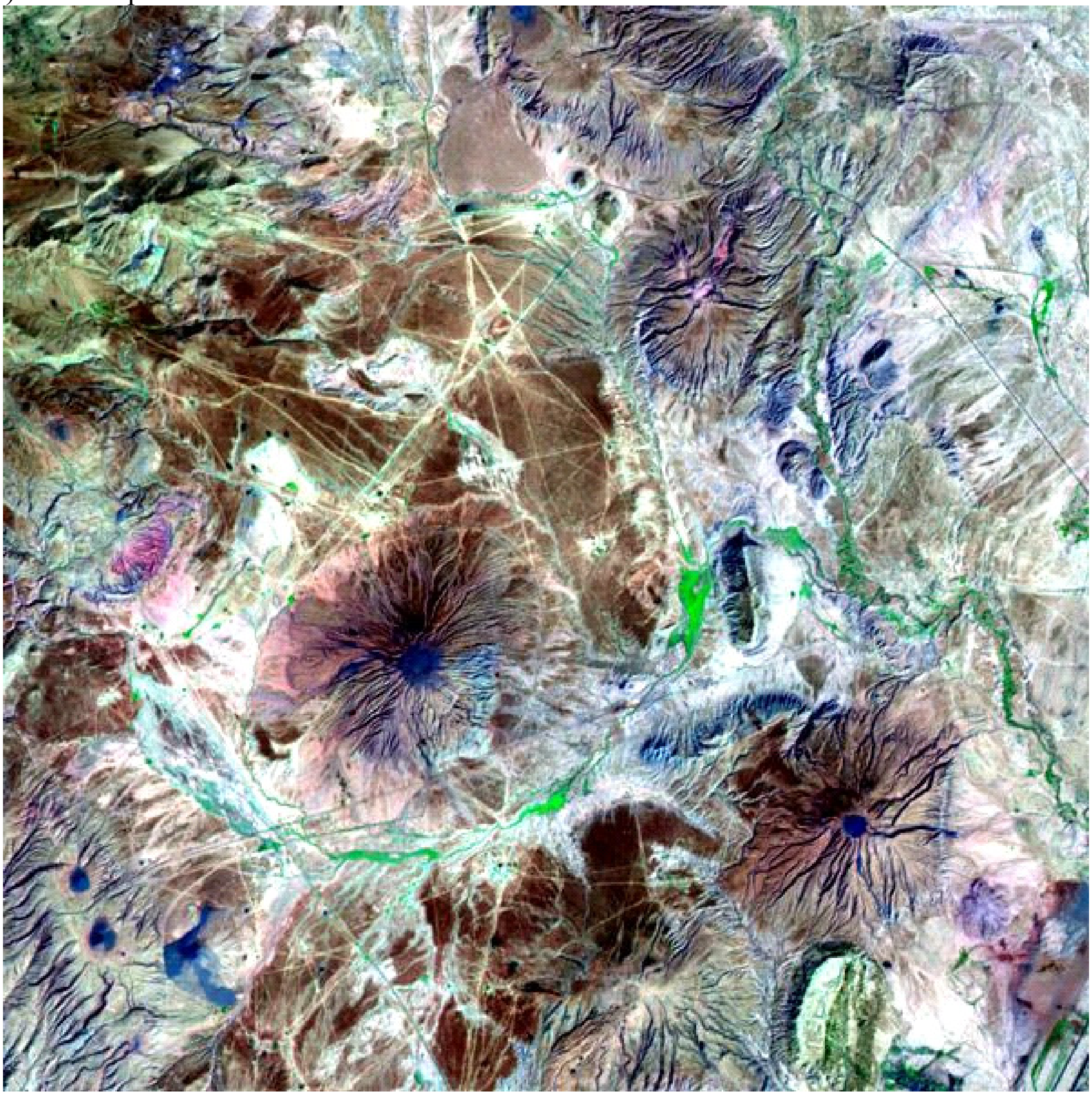

Fig.1. Satellite Image Landsat-7. Bands 7,4,2. Fragment of the distributin of mud volcanoes in the Kura Basin, Azerbaijan.

In this region, vertical subsurface petroleum migration occurs over ten of kilometers between source rock and trap and between accumulations and the surface. In general, this means first that seepage only can provide information for identifying petroleum accumulation potential at basin scales, and second that there may be no direct spatial relationships between subsurface accumulations and surface seeps. Knowledge of the geology and petroleum dynamics of the South Caspian and Kura Basins is key to understanding and using seepage information in exploration. Related controls on fluid flow and seepage range from active mud volcanoes, through high fluid -potential gradients resulting from rapid deposition of fine sediment, to faults and mud diapirism.

Monitoring individual seeps over time contributes to understanding the natural loading of hydrocarbons in the coastal environment. Most seepage occurs along good migration pathways such as active faults. However, in the absence of such focused migration pathways, some vertical migration through sediments probably occurs.

The high sedimentation rate during Pliocene-Miocene times resulted from the large volumes of sediment delivered to the South Caspian by the ancestral Volga and Kura Rivers. The main petroleum

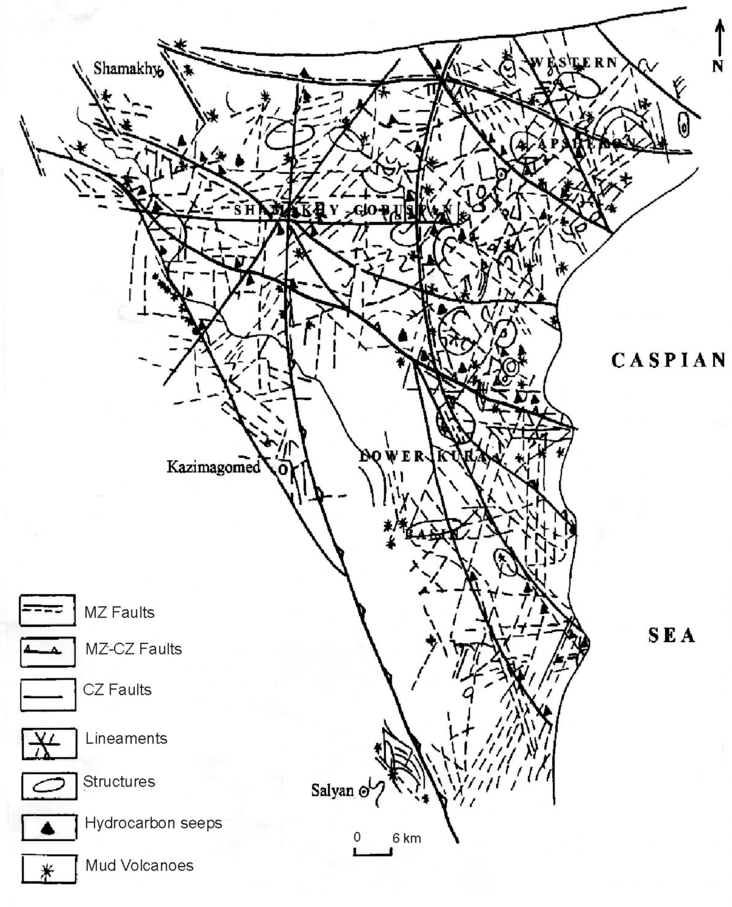

Fig.2. Map showing the faults and the distribution of Hydrocarbon seeps and mud volcanoes Of the South Caspian Basin (western flank)

plays are fluvial-deltaic sand reservoirs structurally bounded by mud volcanoes or faults with, is some cases, a stratigraphic component.

As a result of this analysis we have established that the majority of oil and gas fields are located in regions of fault development. Based upon the density of the fault network, it appears that oil- and gas bearing fields preferentially are formed in areas with lower fracture density. Therefore, regional faults contribute not only to the destruction preservation-existing oil and gas deposits, but they also play a positive role in the formation of the oil and gas accumulations, their preservation, and prevention of groundwater flooding of oil strata. However, it is only passed up to definite borders of the fault density. For example, main oil reserves were determined in Lower Kura Basin and Western-central part of Absheron region, where areas were dislocated by faults (100-280 m/km). Further reduction of oil resources corresponds to the next increase of the dislocation as the region in a whole as the separated structures (Shamakhy-Gobustan region). This regularity is connected with the pools formation, migration and accumulation in the oil and gas traps. This correlation can be explained by noting that important surface oil and gas shows such as mud volcanoes, oil seeps, and other surface features occurred in the zones with increased number and density of faults. According to available statistics, subsurface oil reserves are smaller in these regions.

Abundant bitumen- bearing rocks occur in other structures where the density of structures is very high. For these structures, the commercial oil accumulations have not been determined yet.

Large, sub-latitudinal, regional faults are the proposed pathways for vertical hydrocarbon migration from Mesozoic and Paleogene-Miocene deposits to the surface. Therefore, these faults destroyed any accumulations formed prior to this faulting. Thereby these faults played a negative role in petroleum geology of the region. These ruptures located in the mobile tectonic zones in the Mesozoic age, contributed to the formation of the regional tectonic belts that contained traps for oil and gas. In this way, these regional faults also contributed overall to conditions necessary for the formation of the oil and gas accumulations. So, the faults also played a positive role in petroleum geology of the region. During vertical migration, some part of the hydrocarbons from deep-seated horizons along the faults entered higher trapping units and participated in the formation of hydrocarbon accumulations.

The role of the local faults, developed in the tectonic compression zones formed by sub-longitudinal regional faults, mainly is negative because these fractures are the pathways for hydrocarbon migration to the surface. Intensive oil and gas shows on the surface, which indicate faults disruption of sediments in tectonic compression zones, correlate with an absence of the oil and gas inflows of commercial importance in the test wells drilled in these zones.

Where tectonic zones of Paleogene - Miocene deposits are buried under the massive Pliocene cover, these sub-longitudinal faults can play a positive role for trapping. Because the faults contribute to sub-vertical hydrocarbon migration into overlying horizon reservoirs, oil and gas accumulations from near these tectonic zones, are exceeded only by the Pliocene types of reservoirs.

Thermal modeling shows that oil expulsion from source rocks began during the Miocene and still continuing to the present day in some areas. Thus, oil seepage may be coming directly from the source rocks as well as from leaking accumulations. The occurrence of hydrocarbon seepage directly above reservoirs points to vertical migration of hydrocarbons, despite the fact that groundwater movement might be expected to impact vertical migration.

CONCLUSIONS

In the Kura basin faults related to mud volcanoes are more likely to be continually active, at least on a small scale. The distribution of detected oil and gas seeps in connection with mud volcano structures are good evidence that the mud volcanoes are related to faults. Growth faults resulting from slumping during high sedimentation rates are less likely to be continually active than mud volcano associated faults and are not expected to be as effective as migration conduits to the surface.

Seepage favors good migration pathways. Mud volcano activity and seepage along active faults can be detected and sampled at many stages along the migration and seepage pathways.

Mainly, oil and gas seeps are associated with mud volcanoes, outcrops of oil-bearing strata, and mineral water springs. Most of the seepage occurs in active faulted areas along the Kura Basin. Analysis of satellite data allowed us to determine the geometry of the fault system and around them distributions of hydrocarbon seeps and to predict hydrocarbon potential of the basin.

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