Geochemical Prospecting of Hydrocarbons in Frontier Basins of India*

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Abstract

India has 26 sedimentary basins with a basinal area of approximately 1.8x 10^6 km^2 (excluding deep waters), out of which seven are producing basins and two have proven potential. Exploration efforts in other basins, called "frontier basins" are in progress. These basins are characterized by varied geology, age, tectonics, and depositional environments. Hydrocarbon shows in many of these basins are known, and in few basins oil and gas have flowed in commercial /non-commercial quantities. Within the framework of India Hydrocarbon Vision – 2025 and New Exploration Licensing Policy, there is a continuous increase in area under active exploration. The asset management concept with multi-disciplinary teams has created a demand for synergic application of risk-reduction technologies, including surface geochemical surveys.

National Geophysical Research Institute (NGRI), Hyderabad, India has initiated/planned surface geochemical surveys composed of gas chromatographic and carbon isotopic analyses in few of the frontier basins of India. The adsorbed soil gas data in one of the basins (Saurashtra basin, Gujarat) has shown varied concentrations of CH_4 to C_4H_{10}. The C_1 concentration varies between 3 to 766 ppb and ΣC_{2+}, 1 to 543 ppb. This basin has thin soil cover and the Mesozoic sediments (probable source rocks) are overlain by thick cover of Deccan Traps. The scope and perspective of geochemical surveys in frontier basins of India are presented here.

Introduction

Hydrocarbons generated and trapped beneath the surface seep or leak to the surface in varying but detectable quantities. These phenomena occur because processes and mechanisms such as diffusion, effusion, and buoyancy allow hydrocarbons to escape from reservoirs and migrate to the surface where they may be retained in the sediments and soils or diffuse into atmosphere or water columns (Klusman, 1993; Schumacher and Abrams, 1996). Based on these assumptions, various techniques of surface geochemical prospecting for hydrocarbons have been developed to identify the surface or near-surface occurrences of hydrocarbons. Surface geochemical prospecting for hydrocarbons consist of direct and indirect methods to identify the microseepage. These methods include adsorbed soil gas surveys, microbial techniques, soil salts, bitumen, and trace element techniques, helium emanometry, etc. In order to meet the challenges of India Hydrocarbon Vision 2025 for Exploration & Production sector, a National Facility for surface geochemical prospecting of hydrocarbons has been nucleated at NGRI with a grant from Oil Industry Development Board (OIDB), New Delhi (Kumar et al., 2002a). As a part of this National Facility and under its own Research & Development program, NGRI is carrying-out/planning to carry-out surface geochemical surveys for hydrocarbon prospecting in the frontier onland/offshore basins of India. Adsorbed soil gas surveys have been completed in Vindhyan basin (Chambal Valley) and Kutch onland basin, Gujarat (Kumar et al., 2002b, 2003), and the work in Saurashtra basin is in progress. The results of adsorbed soil gas analyses for light gaseous hydrocarbons in one of the frontier basin (Saurashtra basin) and the future strategies for geochemical surveys in other frontier basins of India are discussed.

Geology and Tectonics of Saurashtra Basin

Saurashtra basin, Gujarat, consists of mostly Mesozoic and Cenozoic rocks (Biswas, 1983; Merh, 1995), and stratigraphically the sequence begins with Cretaceous to be followed upward by the Deccan volcanics, Tertiary and the Quaternary (Figure 1a) The area is largely covered and prominently exposed by the Deccan Trap (basaltic rocks), whose thickness varies from few hundreds to thousands of meters. Traps are underlain by thick Mesozoic sediments (100- 4000 m), which can form potential source rocks. Deccan Trap volcanicity during Late Cretaceous may have generated the requisite thermal conditions and acted as a catalyst in Mesozoic hydrocarbon-generation process. Sedimentation in marine intertonguing environments is considered to have been favorable phenomena for hydrocarbon generation and entrapment. The basin is bounded by three intersecting rift trends, Delhi (NE-SW), Narmada (ENE-WSW) and Dharwar (NNW-SSE). Integrated geophysical studies show that two of the sub-basins of Saurashtra, namely Jamnagar and Dwarka, have significant sediment thicknesses below the Deccan traps and can be considered for future hydrocarbon research.

Soil Sampling and Analytical Procedure

Soil samples from Jamnagar and Dwarka sub basins of Gujarat have been collected in the depth range of 1.2 – 3.5 m using manual augers. The soil cores collected were wrapped in aluminum foils and sealed in poly-metal packs. A total of ~290 soil samples were collected in two phases of field work. The sample location map of the area is given in Figure 1b. In the first and second phase the samples were collected in intervals of 5km and 2 km intervals, respectively, along existing roads.

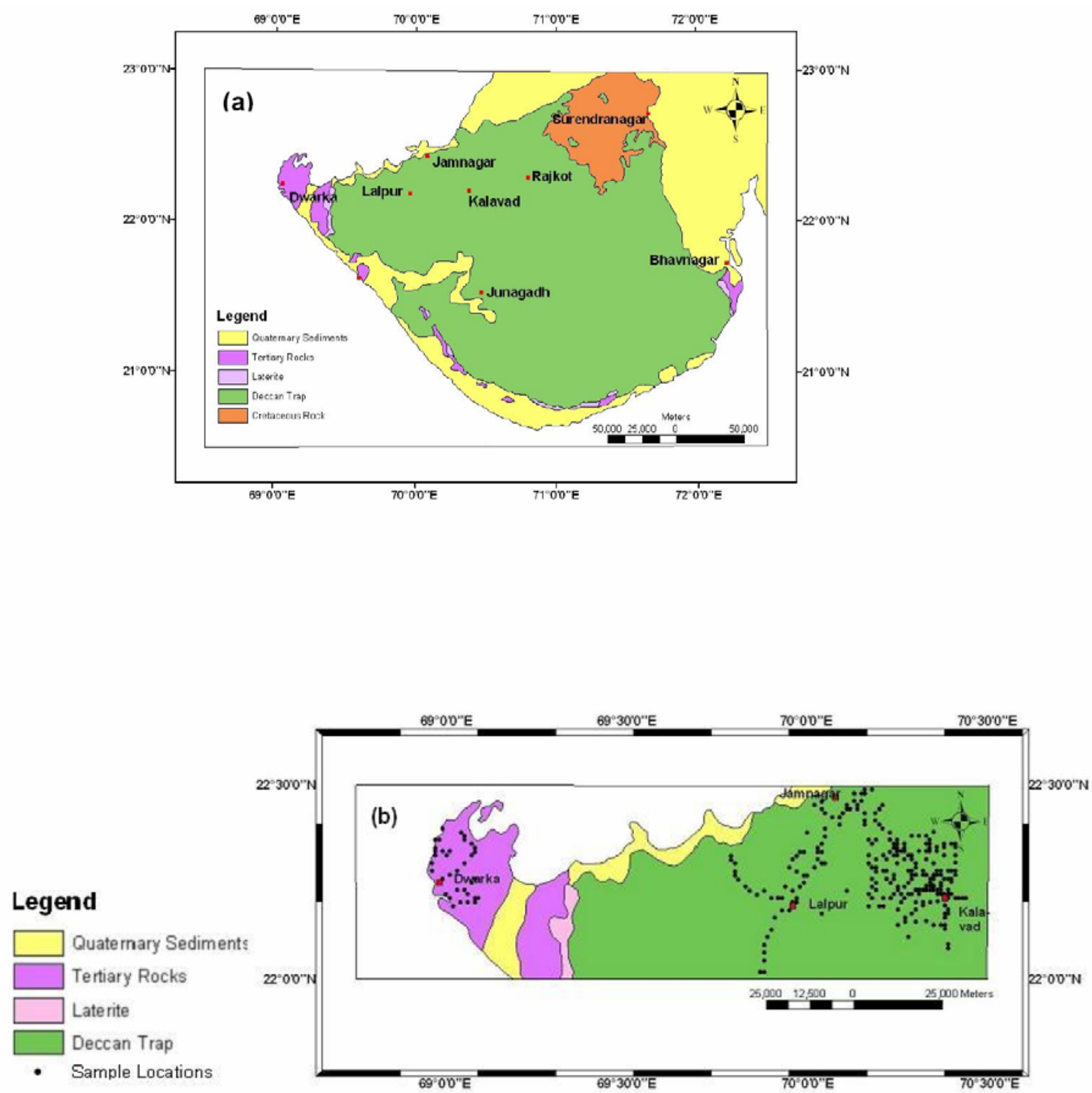

Figure 1. (a) Geological map of Saurashtra basin, Gujarat. (b) Geological map of Dwarka and part of Jamnagar sub-basins, Saurashtra, showing sample locations.

One gram of soil sample is reacted in vacuum with orthophosphoric acid to desorb the soil gases. The CO_2 released was trapped in KOH solution and the light gaseous hydrocarbons are collected by water displacement in a graduated tube fitted with rubber septa. The volume of desorbed gases is recorded, and 500 μl of desorbed gas sample is injected into the Nucon 5765 Gas Chromatograph fitted with ¼" glass-packed column (squalane), programmable temperature controller, and flame ionization detector. The GC was calibrated by using an external standard with known concentrations of methane, ethane, propane, i-butane and n-butane. The quantitative estimation of light gaseous hydrocarbon constituents in each sample was made using peak area measurement as a basis, and the correction for moisture content was applied. The accuracy of measurement of C_1 to C_4 components is < 1 ng/g.

Results and Discussion

The light gaseous hydrocarbon concentrations (CH_4, C_2H_6, C_3H_8, i-C_4H_{10} and n-C_4H_{10}) in soil samples of Jamnagar sub basin vary from 3 to 766, 3 to 261, 9 to 173, 8 to 45 and 5 to 118, in ppb, respectively. The Dwarka sub basin soils are characterized by C_1-C_4 concentrations in the range of 9 to 145, 3 to 130, 2 to 69, 4 to 29 and 6 to 82, in ppb, respectively. Figure 2 depicts the crossplots between C_1-C_2, C_1-C_3, C_2-C_3 and C_1-ΣC_{2+}, showing linear correlation. This indicates that the light hydrocarbon components may have migrated from a thermogenic source, and the effect of secondary alteration during their seepage toward the surface may be insignificant. Pixler (1969) proposed a variation diagram using the ratios of C_1/C_2 and C_1/C_3, etc. to distinguish the non-productive zone from that of oil/gas producing zone. The discrimination diagram of Pixler for samples of Jamnagar and Dwarka sub basins in which methane, ethane, and propane were present suggest that ~70% of these samples fall in the oil-producing zone and the rest in the gas zone. The concentration of ΣC_{2+} is plotted in Figure 3 into three groups (i.e., ΣC_{2+} >100 ppb, ΣC_{2+} = 50-100 ppb, and ΣC_{2+} <50 ppb) and shows that the samples around Jamnagar, Kalavad, and Lalpur are characterized by higher ΣC_{2+} values. This suggests that hydrocarbon generation has taken place in the basin and the area may prove to be warm for future hydrocarbon exploration. The present geochemical data support the earlier geological and geophysical findings.

The adsorbed soil gas surveys carried out by NGRI for Directorate General of Hydrocarbons, New Delhi in Vindhyan basin (Chambal Valley) and Kutch onland basin have also demarcated the warm areas for hydrocarbon research and exploration. The efforts to conduct detailed geochemical surveys in other frontier basins of India are in progress.

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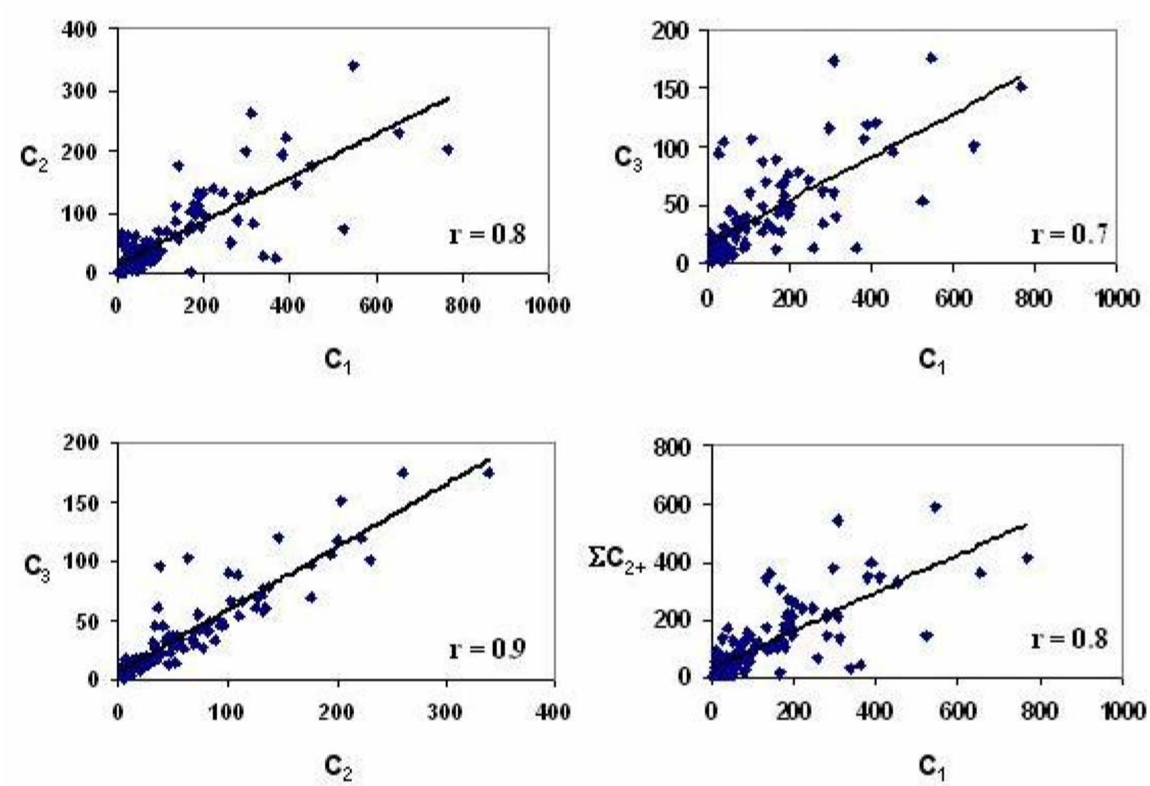

Figure 2. Crossplots of C_1-C_2, C_1-C_3 and C_1-ΣC_{2+} for soil samples of Jamnagar and Dwarka sub-basins, Saurashtra.

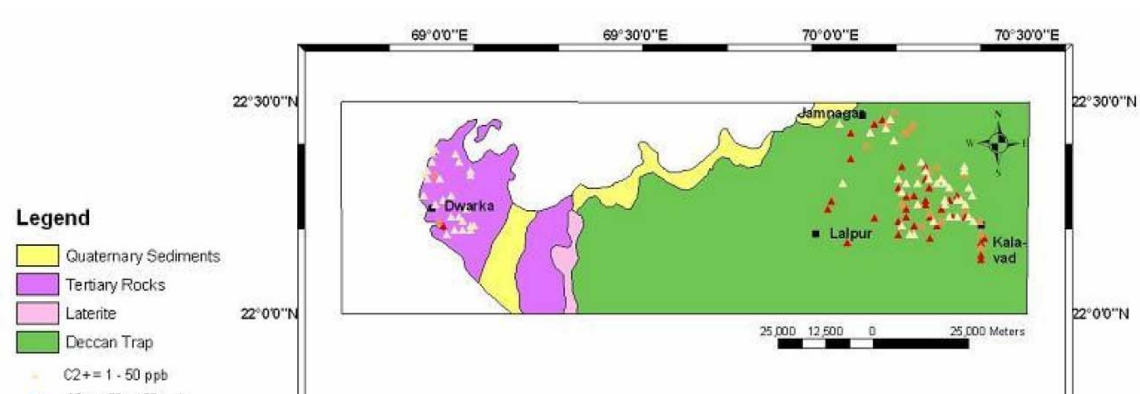

Figure 3. Concentration of ΣC_{2+} in soil samples plotted on the geological map of Dwarka and part of Jamnagar sub-basins, Saurashtra. The concentrations are depicted in three different colors by triangles.

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