Hydrocarbon Prospects in Sub-Trappean Mesozoic Deccan Syneclise, India: Evidence from Surface Geochemical Prospecting

By
C. Vishnu Vardhan[1*], B. Kumar[1], C.J. Kumanan[2], Devleena Mani[1], and D. J. Patil[1]

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[1]National Geophysical Research Institute, Hyderabad (baleshk@yahoo.com)
[2]Center for Remote Sensing, Bharathidasan Universtiy, Tiruchirappalli

*Presently with Hardy Exploration and Production (India) Inc. Chennai (vishnucvardhan@gmail.com)

Abstract

The Mesozoic sediments contribute around 54% of the oil and 44% of the gas reserves of the world (Bois et al. 1982). Indian Mesozoic basins occupy an area of about 400 x 10^3 sq. km and are characterized as frontier basins under category II - IV. These basins are mostly overlain by the Deccan Traps of Late Cretaceous age and are least explored. Deccan Syneclise is one of the largest Mesozoic basins in India, covering an area of ~ 273 x 10^3 sq. km. Geophysical studies have inferred hidden sub-trappean Mesozoic sediments with thickness up to 2.5 km. It is considered that requisite heat generation due to Deccan Trap volcanism soon after the Cretaceous sedimentation may have acted as a catalyst in hydrocarbon generation. Surface geochemical prospecting surveys along with carbon isotopic studies have been used to assess hydrocarbon generation potential of this part of the basin. The area adjoining Nandurbar beneath Narmada-Tapti region of Deccan Syneclise was selected for geochemical studies where geophysical studies have shown considerable sediment thickness. Surface geochemical studies indicate the generation of light gaseous hydrocarbons, C1 and ΣC_{2+} in the range of 3 to 1187 ppb and 1 to 1449 ppb, respectively. The carbon isotopic signatures of selected soil gas samples (δC^{13} CH_4 in the range of –24 to –39.4‰ PDB) suggest thermogenic origin.

Introduction

The large tract beneath the Upper Cretaceous-Paleocene Deccan Trap in western India is called Deccan Syneclise (Figure 1). It is one amongst the 26 sedimentary basins of India and is grouped under category IV: i.e., potentially prospective basin. Geophysical studies have revealed hidden Mesozoic sedimentary basins under the Deccan Traps. Surface Geochemical Surveys have been carried out in one of the prospective zones to assess the hydrocarbon prospectivity of the basin. Geochemical prospecting of hydrocarbons identifies the surface or near-surface occurrences of hydrocarbons or their alteration products, which are due to macro/micro seepage of the subsurface hydrocarbon occurrences. The micro/macro seepage is an established phenomenon, and these 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. Microseepage of hydrocarbons has led to the discovery of many important petroleum producing areas in the world.

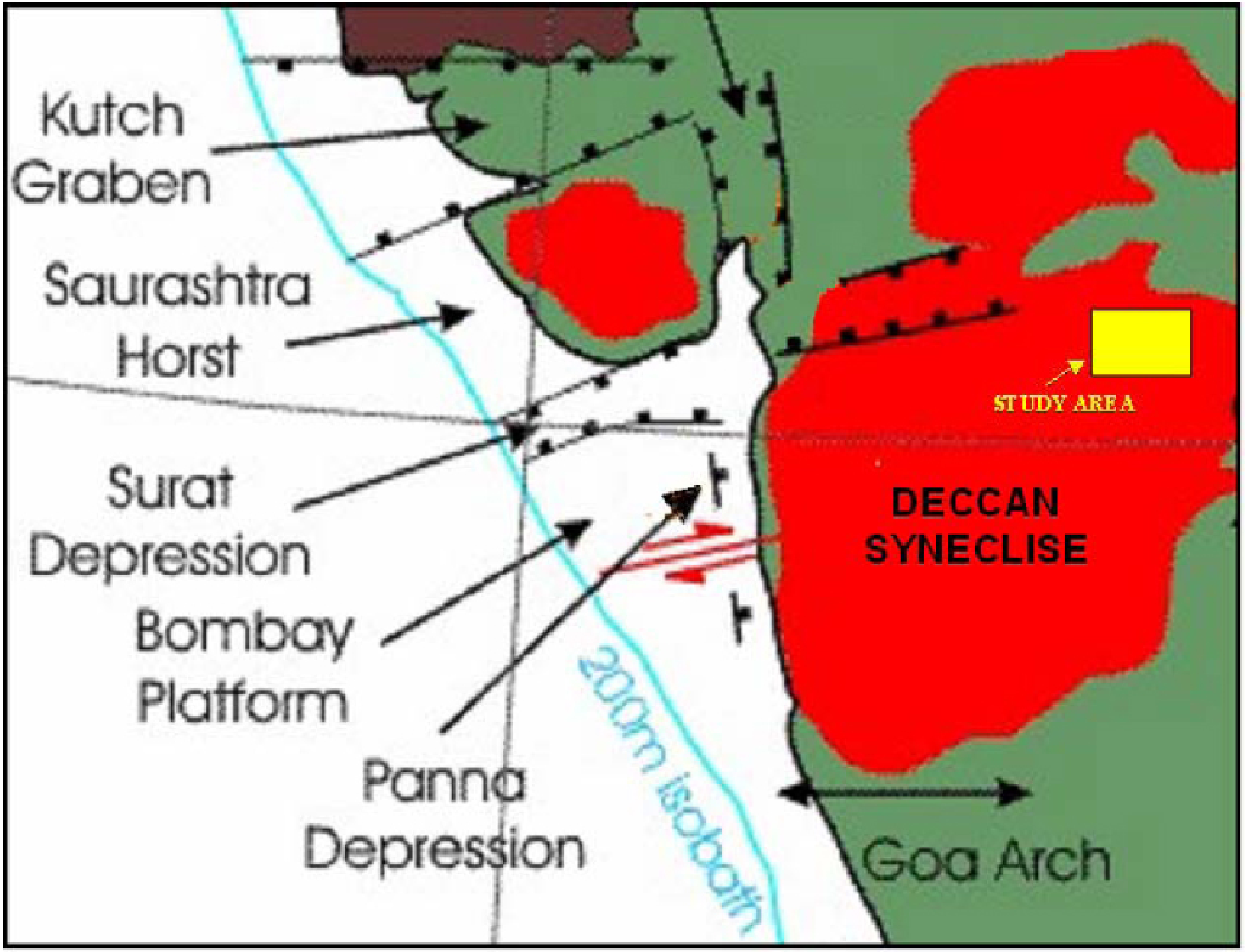

Figure 1 Geological and tectonic map of Deccan Syneclise (modified after Gombos et. al., 1995).

Deccan Syneclise

Deccan Syneclise is an intracratonic sedimentary basin covering an area of ~273 x 10^3 sq. km. The basin is mostly covered by Deccan Traps, with the exposure of Bagh and Lameta beds in the adjoining areas. The Deccan trap thickness varies largely and is about 100 m in the northeastern part and >1500 m towards the west coast of India. Below the Deccan Traps in the Narmada-Tapti region a hidden Mesozoic basin has been mapped in the form of two grabens separated by a small horst. In the southern part a larger Tapti graben with sediment thickness of about 2000 m is revealed, whereas in the northern part there is a smaller Narmada graben with sediment thickness of about 1000 m (Kaila, 1989). Integrated geophysical studies carried out by National Geophysical Research Institute (NGRI), Hyderabad and Directorate General of Hydrocarbons (DGH), New Delhi, have revealed the presence of Mesozoic sediments with thickness of about 1000m to 2500 m in the central part of Narmada-Tapti region (DGH, Annual Report 2003-04). The sediments of this Mesozoic basin were deposited in a larger Mesozoic sea, which extended from Narmada- Tapti region through Saurashtra, Kutch, up to Sind and Salt Range in the form of horseshoe. The Moho configuration under the Deccan-Trap-covered area reveals the depression in the central part extending in an ENE-WSW direction, which almost coincides with the region of hidden Mesozoic basin (Kaila, 1989). The marine transgressions and regressions that occurred in west-central India before the Deccan volcanicity might have favored the deposition of organic-rich source rocks. Further, the Deccan Trap volcanism during Late Cretaceous might have generated the requisite thermal conditions and acted as a catalyst in a Mesozoic hydrocarbon-generation process (Biswas and Deshpande, 1983). The generalized stratigraphy of Deccan Syneclise is given in Table 1.

Soil Sampling and Analytical Procedure

A total of 50 soil samples were collected in part of Deccan Syneclise at an interval of 5 km along existing roads. The sample location map of the area is given in Figure 2. Samples 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.

One gram of soil sample is reacted under vacuum with orthophosphoric acid to desorb the soil gases. The CO_2 released was trapped in KOH solution and the light gaseous hydrocarbons were collected by water displacement in a graduated tube fitted with rubber septa. The volume of desorbed gases is then recorded, and 500 µl of desorbed gas sample is injected into the Varian CP-3800 Gas Chromatograph fitted with Porapak 'Q' column, 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, n-butane, i-pentane, and n-pentane. The quantitative estimate 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_5 components is < 1 ng/g.

AGE	FORMATION/ GROUP	ANTICIPATED MAX. THICKNESS	LITHOLOGY
Recent	Alluvium		
Pleistocene	Laterite		
Early Paleocene to Late Cretaceous	Deccan Trap	1 to 2 km	Basalt
		Unconformity	
Late Cretaceous	Lameta Beds		Arenaceous limestone
Middle Triassic	Upper Gondwana	2km	Sandstone & Shale
		Unconformity	
Early Triassic to Late Carboniferous	Lower Gondwana	1.5 km	Sandstone & Shale interbedded with coal
		Unconformity	
Basement with thin outliers of Vindhyan sediments at places			

Table 1 Generalized stratigraphy of Deccan Syneclise (Oil Infraline- Oil and Gas Exploration and Production in India, 2006).

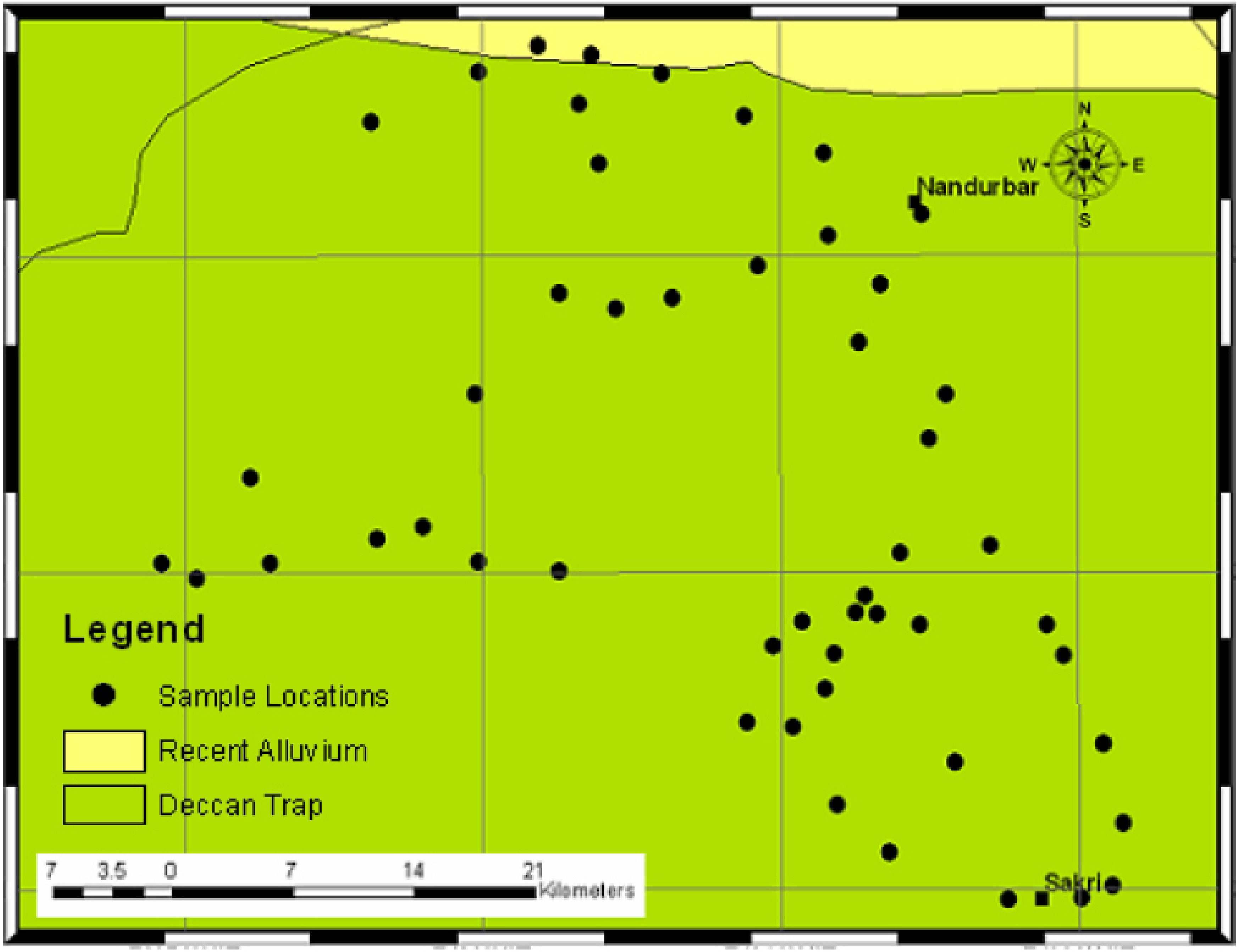

Figure 2. Geological map of part of Deccan Syneclise showing sample locations.

Results and Discussion

The light gaseous hydrocarbon concentrations (CH_4, C_2H_6, C_3H_8, i-C_4H_{10}, n- C_4H_{10}, i-C_5H_{12} and n-C_5H_{12}) in soil samples of Deccan Syneclise vary from 3 to 1187 (CH_4), 1 to 633 (C_2H_6), 1 to 504 (C_3H_8), 1 to 123 (i-C_4H_{10}) and 2 to 159(n-C_4H_{10}) in ppb, apart from i-C_5H_{12} and n-C_5H_{12} in few samples. The contour map of C_1 and ΣC_{2+} are plotted in Figures 3 and 4 and show that the samples south of Nandurbar are characterized by higher C_1 and ΣC_{2+} values. The crossplots between C_1-C_2, C_1-C_3, C_2-C_3 and C_1-ΣC_{2+}, show linear correlation ($r > 0.8$), which indicates that the light gaseous hydrocarbon may have migrated from the same source, and the effect of secondary alteration during their seepage toward the surface may be insignificant.

Analyses of the gas samples for the measurement of δC^{13} in methane were carried out using Thermo Finnigan Delta Plus XP Isotope Ratio Mass Spectrometer. The δC^{13} values are reported as parts per thousand (‰) relative to the Peedee belemnite (PDB) standard (precision is ±0.3%). δC^{13} in methane lies in the range of –24 to –39.4‰ PDB suggesting a thermogenic origin.

The presence of C_1-C_5 hydrocarbons in the adsorbed soil gases in the samples collected from part of Deccan Syneclise indicates that hydrocarbon generation has taken place in the basin and gases are derived from thermogenic source (Klusman, 1993; Kumar et al., 2004; Schumacher and Abrams, 1996). The geochemical studies suggest that this part of Deccan Syneclise may prove to be a warm area for future hydrocarbon exploration and exploitation.

Conclusions

Evidence of generation of hydrocarbons derived from possible thermogenic source beneath the Deccan Traps may open new vistas for commercial discovery of oil/gas in the Mesozoic of India.

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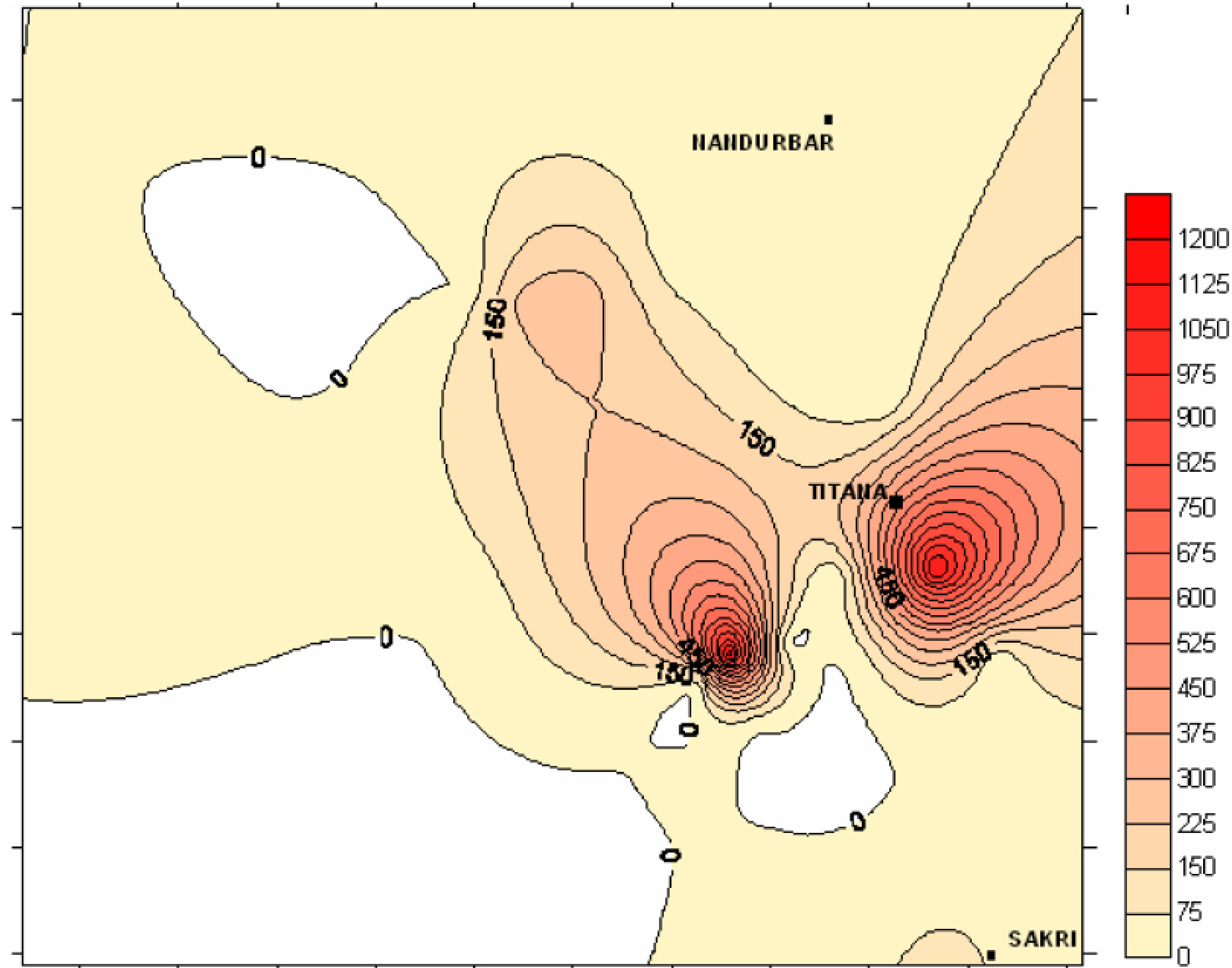

Figure 3. Contour map showing the concentrations of methane in ppb for soil samples collected from part of Deccan Syneclise.

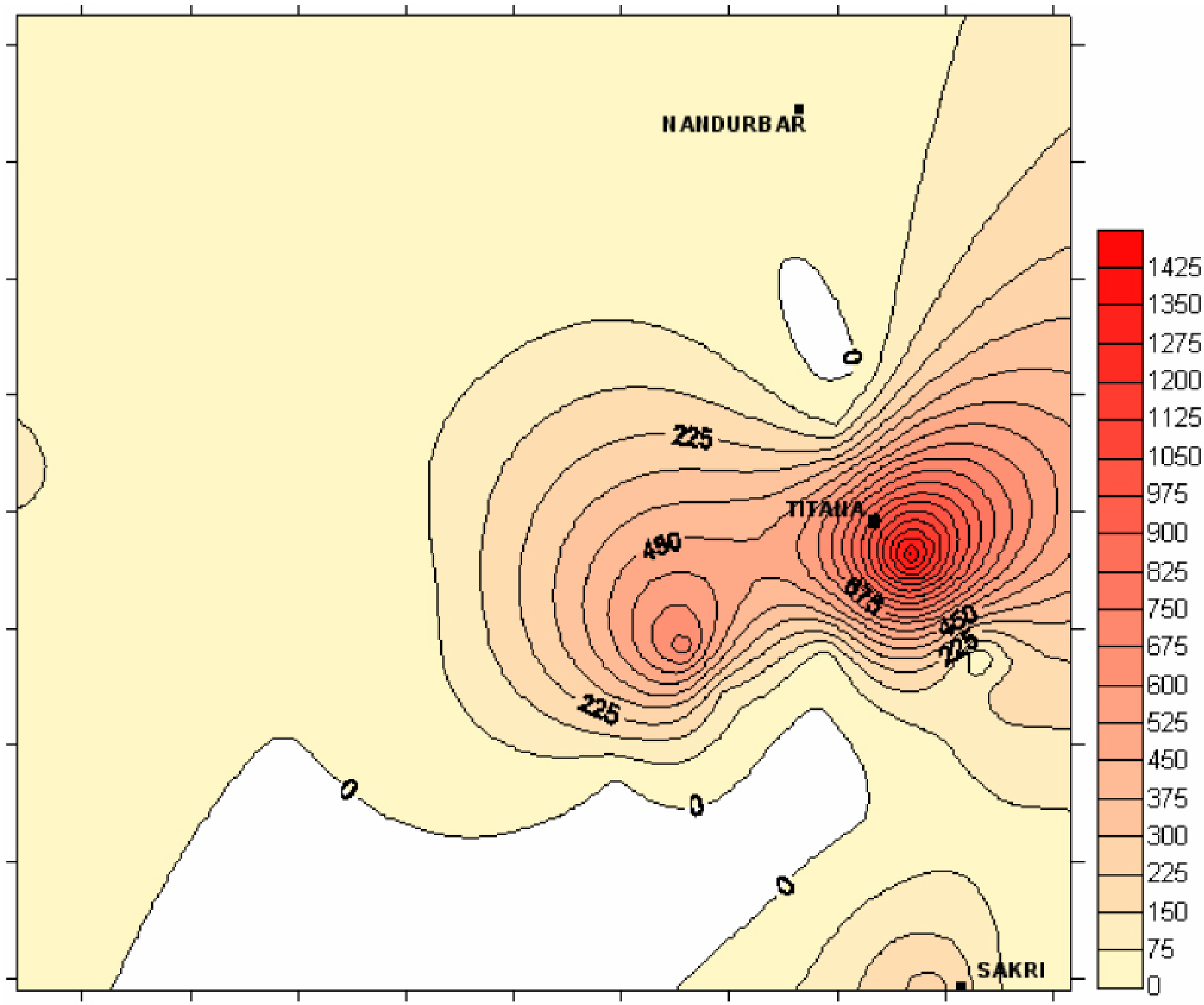

Figure 4. Contour map showing the concentrations of ΣC_{2+} in ppb, for soil samples collected in part of Deccan Syneclise.