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Significance of Trace metal anomalies in finding hydrocarbon micro-seepage in petroliferous areas of Krishna Godavari Basin, India

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Summary

The long-term seepage of hydrocarbons, either as macro or micro seepage, can set up near-surface oxidation reduction zones that favor the development of a diverse array of chemical and mineralogic changes. The bacterial oxidation of light hydrocarbons can directly or indirectly bring about significant changes in the pH and Eh of the surrounding environment, thereby also changing the stability fields of the different mineral species present in that environment. The paper reports the role of hydrocarbon micro seepage in surface alterations of trace metal concentrations. In this study trace metal alterations were mapped that appear to be associated with hydrocarbon micro seepages in the oil/gas fields. The soil samples were collected near oil and gas fields of Tatipaka, Pasarlapudi areas of Krishna Godavari Basin, Andhra Pradesh from a depth of 2 - 2.5m. The paper reports the chemical alterations associated with trace metals in soils that are related to hydrocarbon micro seepages above some of the major oil and gas fields of petroliferous region of Tatipaka and Pasarlapudi areas of Krishna Godavari Basin, India. The soil samples for trace metals; Scandium (Sc), Vanadium (V), Chromium (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Barium (Ba) and Strontium (Sr) were analyzed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The concentrations of Sc (8.01 to 39.737 ppm), V (197.31 to 489.51 ppm), Cr (106.5 to 287.54 ppm), Co (30.92 to 51.94 ppm), Ni (65.04 to 109.95 ppm), Cu (87.73 to 131.35 ppm), Zn (88.51 to 470.84 ppm), Ba (263.52 to 3091.55 ppm) and Sr (119.45 to 217.62 ppm) were obtained. Integrated studies of trace elements over adsorbed light gaseous hydrocarbons (ΣC_{2+}) anomalies showed good correlation with the existing oil and gas wells. The increase in trace metal concentrations near oil/gas producing areas, suggests a soil chemical change to a reducing environment, presumably due to the influence of hydrocarbon micro seepage, which could be applied with other geo-scientific data to identify areas of future hydrocarbon exploration in the frontier areas.

Key words: *Hydrocarbons, micro seepage, trace metal alterations, adsorbed soil gas, Krishna Godavari Basin.*

Introduction

The long-term seepage of hydrocarbons, either as macro or micro seepage, can set up near-surface oxidation reduction zones that favor the development of a diverse array of chemical and mineralogic changes (Donovan, 1974; Petrovic et al., 2008). The bacterial oxidation of light hydrocarbons can directly or indirectly bring about significant changes in the pH and Eh of the surrounding environment, thereby also changing the stability fields of the different mineral species present in that environment. These changes result in the precipitation or dissolution and remobilization of various mineral species and elements, such that the rock column above a leaking petroleum accumulation becomes significantly and measurably different from laterally equivalent rocks (Price, 1986). It is also believed that hydrocarbons along with inorganic components associated with oil are continuously migrating to the surface which forms the basis for surficial petroleum investigations with regard to trace metals (Petrovic et al., 2008). The alterations occur because leaking hydrocarbon set up near surface oxidation and/or reduction zones that favor the development of a diverse array of chemical and mineralogical changes. The paper reports the chemical alterations associated with trace metals in soils that are related to hydrocarbon micro

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seepages above some of the major oil and gas fields of petroliferous region of Tatipaka and Pasarlapudi areas of Krishna Godavari Basin, India.

Geology of the Study Area

The Krishna-Godavari Basin is a pericratonic rift margin system with an archean basement on the east coast of the Indian Peninsula. It covers an area of 28,000 sq. km on land and 24,000 sq. km off land up to 200m bathymetry. The basin lies between 15°30' to 17° N latitudes and 80 to 82 30' E longitudes. The basin is divided into Krishna, East Godavari and West Godavari depressions separated by basement highs at Bapatla and Tanuku horsts, respectively (Rao, 1993). The East Godavari sub-basin is further divided in to the Mandapeta Graben, Narsapur- Razole High and Amalapuram high. The Matsyapuri-Palakollu and Mori faults are the two major NE-SW faults. The West Godavari sub-basin is sub-divided into the Gudivada and Bantumilli graben, separated by the Kaza-Kaikaluru horst. The tertiary alluvium sediments brought by Godavari delta system attained greater thickness south of the Matsyapuri-Palakollu fault as a result of continuous subsidence and growth fault related tectonics. The depositional environment varies from continental to lagoonal, marine, littoral, infraneritic and deltaic conditions. The sediment yield rich faunal assemblages like arenaceous foraminifera (Ammobaculites sp., Ammodiscoides sp., etc.), Trigonia, Inoceramus, Lima, Pecten, Belemnites, Helicoceras, Cardita, Lamellibranchs and Gastropods etc. (Sastri et al., 1973). Geological location map of Krishna-Godavari Basin in shown in Fig.1.

Materials and Methods

A total of 50 soil samples were collected from selected sites near oil and gas fields of Tatipaka, Pasarlapudi areas of Krishna Godavari Basin, Andhra Pradesh. The soil samples were collected from a depth of 2 - 2.5 m using a hollow metal pipe by manual hammering to the required depth. About 500g of core soil samples were collected and wrapped in aluminum foil and sealed in poly-metal packs used for adsorbed soil gas analysis and trace element concentrations. The physico-chemical properties such as pH, EC, TDS and Eh in soil samples were analyzed on pH/EC/Eh Bench top meter. The light gaseous hydrocarbons were analyzed using Gas Chromatograph (GC). The soil samples Trace elements were analyzed using ICP-MS.

Results and Discussions

The pH of the soils in the study area ranges from 5.72 to 8.88. The Ec ranges from 76 to 3490 µ S/cm at 25°C. Electrical conductivity is found to be a useful parameter to locate gas and gas associated oil reservoirs. The recognizable increase in electrical conductivity above the areas of gas accumulation (Heemstra et al., 1979), but have little effect over oil and barren areas. The oxidation-reduction potential (Eh) in the near surface soils of the study area ranged from 142 to 295 mV. Eh measures the tendency of an environment to oxidize or reduce substrates and the values decrease from oxidizing to reducing environments.

Trace element geochemistry

The concentrations of each of the trace elements ranged between for Sc (8.01 to 39.737 ppm), V (197.31 to 489.51 ppm), Cr (106.5 to 287.54 ppm), Co (30.92 to 51.94 ppm), Ni (65.04 to 109.95 ppm), Cu (87.73 to 131.35 ppm), Zn (88.51 to 470.84 ppm), Ba (263.52 to 3091.55 ppm) and Sr (119.45 to 217.62 ppm). The concentrations of trace elements in normal soils are as follows for Sc (7 ppm), V (90 ppm), Cr (70 ppm), Co (8 ppm), Ni (50 ppm), Cu (30 ppm), Zn (90 ppm), Ba (500 ppm) and Sr (250 ppm) (Bowen, 1979). It was observed that trace elements concentrations were tremendously increased when compared with normal concentration in the soils. The concentration distribution maps of these elements in the area can be seen with their respective composite anomaly maps with ΣC2+ (Figs. 2 and 3). The trace elements anomalies are located in Tatipaka, Pasarlapudi and Pasarlapudi Lanka. Trace elements concentration distribution showed good correlation with the existing wells. Increased amounts of soluble Ni, V, Cu, Cr, Zn and Co have been observed in the reducing environment caused by the seepage of hydrocarbons.

Integration with adsorbed soil gases

Integrated maps of trace elements over adsorbed light gaseous hydrocarbons (ΣC_2+) anomalies showed good correlation with the existing oil and gas wells (Figs. 2 and 3). The study shows that most of the trace elements follow a halo pattern encircling an apical pattern of hydrocarbon seepage indicating the presence of reduced body in the subsurface. Siegel (1974) and Duchscherer (1983) reported that trace element associations form organometallic compounds, are found "haloed" or concentrated over or around underlying hydrocarbon reservoirs.

Conclusion

The trace elements concentrations showed excellent correlation with the existing oil and gas wells in the study area. The trace element anomalies are found to be in good agreement with geological information available for the area and correlated with the major oil and gas fields of Krishna-Godavari Basin. The composite anomaly maps of ΣC_2+ and trace elements correlate well with the underlying hydrocarbon reservoirs in the study area. The increase in trace metal concentrations near oil/gas producing areas, suggests a soil chemical change to a reducing environment, presumably due to the influence of hydrocarbon micro seepage, which could be applied with other geo-scientific data to identify areas of future hydrocarbon exploration in the frontier areas.

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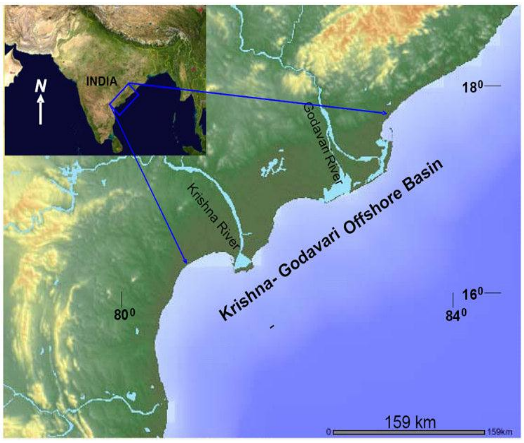

Fig. 1: India map showing location of Krishna-Godavari Basin.

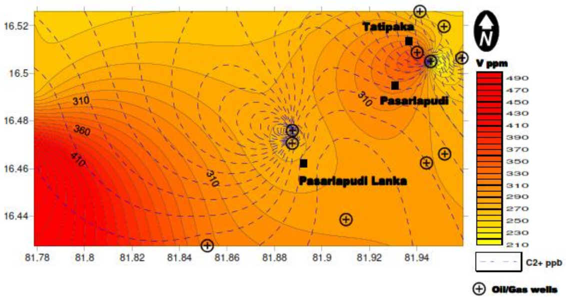

Fig. 2 Composite map of Vanadium and adsorbed soil gas concentration in oil and gas fields of Krishna Godavari Basin study area.

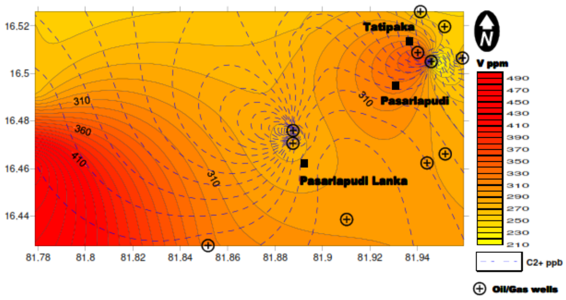

Fig. 3 Composite map of Cobalt and adsorbed soil gas concentration in oil and gas fields of Krishna Godavari Basin study area.

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