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Anomalous thermal structure and upwarping of mafic crust below the K-T boundary impact site offshore near Mumbai: Implication for Hydrocarbon occurrences

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Summary

Western India and adjoining offshore regions are known to be quite favourable for the generation and maturation of hydrocarbons. Our present study indicates that these regions are associated with anomalous crustal and thermal structure with an extremely high dose of heat flow from the mantle which may be related to the bolide impact- triggered Deccan volcanism at the K-T boundary. Shallow melting conditions (about 45 km depth below the northern and eastern part of Mumbai offshore region) apparently led to (1) thermal uplifting and consequent exhumation of the mafic (granulitic / amphibolitic) crust to shallow subsurface levels ,and (2) amplification of thermal maturation process in oil and gas rich Tertiary sediments in this region.

Introduction

Recent studies regarding the evolution of hydrocarbon bearing western continental region and adjacent offshore have focused on two possible events which took place at around 65 Ma: (i) a comet or bolide impact near offshore Mumbai, and (ii) massive Deccan volcanic event, which forms one of the largest flood basaltic eruption on the continental surface of the earth, covering an original area of around 1 million sq.km (Fig.1).

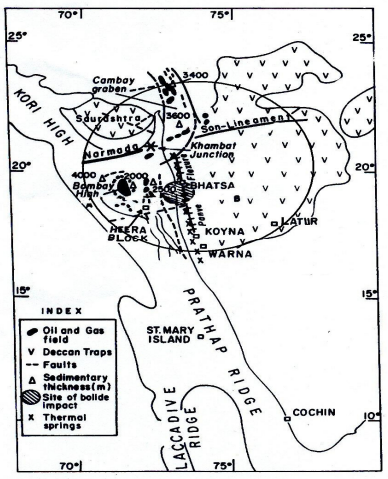

Figure 1: Geotectonic structure of western India and adjoining offshore region. Oil / gas field locations and tectonic structure within Cambay graben and Mumbai offshore region are adopted from Raju and Srinivasan (1993). Sedimentary thicknesses are from Negi et al. (1992b) and Pandey et al. (1984).

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The impact structure has now been demarcated (Negi et al., 1992a; Chatterjee-dia-sm.jpg) and independently confirmed by a detailed study of Parthasarathy et al. (2008). In Anjar intertrappean sediments, high pressure phase of fullerenes have been found, and co-exist with high iridium (Fig.2), suggesting the extra terrestrial impact during the K-T boundary. The iridium poor sediments at Anjar contain the carbonaceous matter, consisting of poly aromatic hydrocarbons (PAH), which could be the precursor material for the fullerene formation. It is interesting to note that such PAH were also found in the acid-resistant residue of the carbonaceous chondrite Murchison.

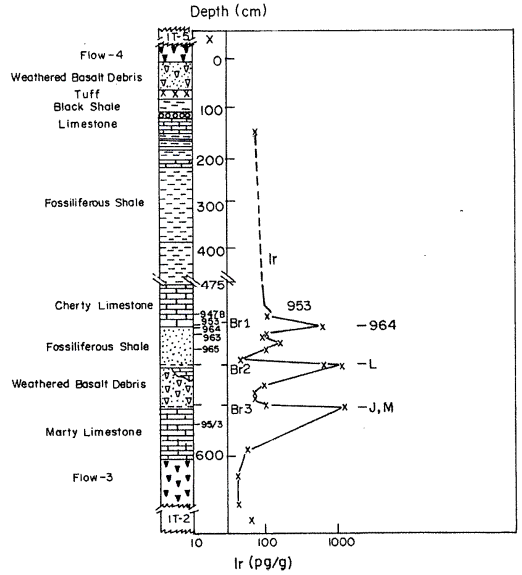

Figure 2 : Location of Ir anomalies and high-pressure fullerene occurrences in the intertrappean beds at Anjar (Kuchchh) (Parthasarathy et al., 2008).

Results

Our studies indicate that the K-T impact near offshore Mumbai was responsible for triggering Deccan volcanism, which led to Seychelles breakup, caused large scale structural uplift in an area of about 400 km diameter and severely affected the region lying between 16^0 and 24^0 N and 70^0 to 75^0 E (Negi et al., 1992a; Pandey et al., 1995). It also modified the thermal and structural configuration underneath, resulting into an extremely high input of heat flow from the mantle (~40-90 mW/m^2). Melting conditions are expected at an extremely shallow depth of about 40-45 km below northern Cambay graben and northern and eastern part of Mumbai offshore region (Fig.3) which contains large hydrocarbon reserve. Expected temperatures at the depth of 1 and 2 km are likely to be in the range of 50-100^{0}C and 100-150^{0}C respectively. Such hotter thermal conditions underneath resulted into thermal uplifting of this region and exhumation of the mafic granulitic (and amphibolitic) crust to shallow subsurface levels.

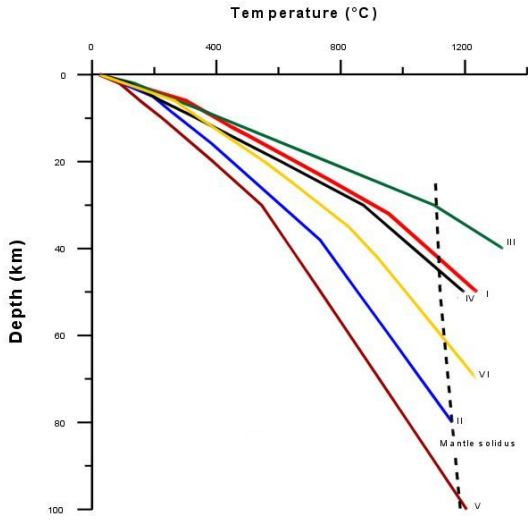

Figure 3 : Temperature-depth profiles for different geotectonic segments of western India and adjacent offshore region. I : North Cambay graben, II : South Cambay graben, III : Konkan thermal province, IV : N&E Mumbai offshore, V : SW Mumbai offshore, VI : Kachchh rift zone.

In Table 1, we show the average distribution of whole rock major oxides (in wt%) in the crystalline basement of 1993 Latur earthquake region (Maharashtra) and offshore Mumbai high region. For comparison, average composition of Archean intermediate granulites from two major studies are also included. The distribution of major element data conforms to the intermediate nature of the rock, commonly found at mid-crustal levels. Total alkali-silica (TAS) diagram (Fig.4) independently supports the intermediate nature of the basement both below the Latur as well as offshore Mumbai high, which plot in the field of trachy- andesite. Interestingly, there is also a report which

suggests the occurrence of 502±25 Ma Pan African granulitic basement in HBM-1 borehole of the Heera oil field of the Mumbai offshore basin (Rathore et al., 2000).

SAMPLE	KIL	BH-36[X]	IGR-1[*]	IGR-2[+]
N	3	7	102-106	115
SiO_2	58.17	57.69	58.30	58.39
TiO_2	0.81	1.21	0.83	0.83
Al_2O_3	15.81	15.97	16.30	15.57
Fe_2O_3	7.29	6.14	8.11	8.87
MnO	0.11	0.07	0.11	0.12
MgO	3.07	3.52	3.60	3.66
CaO	6.07	2.66	6.20	6.07
Na_2O	4.15	6.29	4.00	3.81
K_2O	2.46	2.50	1.55	1.76
P_2O_5	0.28	0.45	0.27	0.26

Table-1 Whole rock major oxides (wt %) compositions of the Killari (KIL) and offshore Bombay high (BH-36) crystalline basement. IGR1:Archean intermediate granulite (and amphibolite) facies rocks ; IGR2: Archean intermediate granulites of central east China. x Rathore et al..(2004), * Rudnick and Fountain (1995), + Gao et al. (1998) for central east China

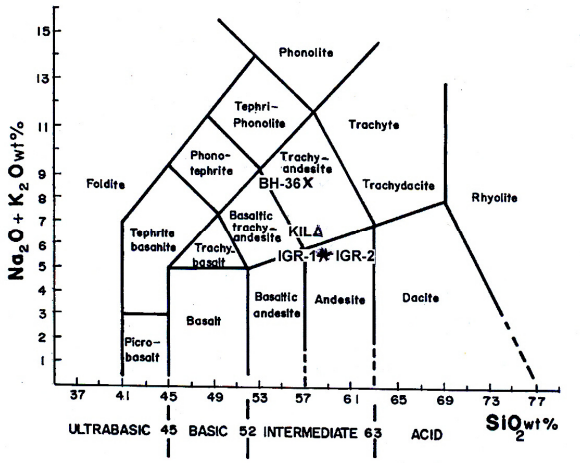

Figure 4: Total alkali-silica (TAS) diagram (LeBas et al., 1986) showing plot of Killari borehole crystalline basement samples (KIL) and offshore Mumbai high (BH-36). IGR-1 : Archean intermediate granulite (and amphibolite) facies rocks (Rudnik and Fountain, 1995); IGR-2 : Archean Intermediate granulite, central east China (Gao et al., 1998).

Conclusions

We conclude that the southern granulitic terrain basement, which apparently underlies below the eastern Dharwar craton (Pandey et al., 2002; Agarwal and Pandey, 2004; Mall et al., 2008; Pandey et al., 2009) possibly extends even further to the Mumbai offshore region also. Petrologically, crystalline basement of Latur and Heera oil field are similar containing Cpx, Opx, quartz, feldspar, amphiboles, biotite, Fe-Ti oxide, sphene, etc. thus, indicating that almost entire upper granitic-gnessic crust may have been eroded away from the certain segments of Mumbai offshore region. This can be explained due only to the upliftment of the crust of this region during pre-Deccan Trap eruptive period by thermal upwelling. Such an evolutionary process alone can bring mafic crust to such shallow subsurface levels.

Lack of the presence of significant thickness of highly radioactive granitic-gnessic crust in the western continental and adjacent offshore would also mean that the major heat flow contribution is from the mantle which is enhancing the process of thermal maturation in oil and gas rich Tertiary sediments.

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